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HARVEST MANAGEMENT AND RECOVERY OF SNAKE RIVER-SALMON STOCKS

Recovery Issues for Threatened and Endangered Snake River Salmon
Technical Report 7 of 11

Technical Report 1993

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HARVEST MANAGEMENT AND RECOVERY OF SNAKE RIVER SALMON STOCKS

Recovery Issues for Threatened and Endangered Snake River Salmon
Technical Report 7 of 11

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[1] **Mobrand Biometrics, Inc., Vashon Island, WA**

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EXECUTIVE SUMMARY

Management measures to regulate harvest have grown increasingly complex over the past decade in response to the needs for improved protection for some salmon runs and to alter harvest sharing between fisheries. The development of management plans that adequately'address both needs is an immensely complicated task, one that involves a multitude of stocks, each with its own migration patterns and capacity to sustain exploitation. The fishing industry that relies on these fish populations is also highly diverse. The management task is made especially difficult because the stocks are often intermingled on the fishing grounds, creating highly mixed aggregates of stocks and species on which the fisheries operate. This situation is the one confronting harvest managers attempting to protect Snake River salmon.

This report provides an overview of some of the factors that will need to be addressed in assessing the potential for using harvest management measures in the recovery of Snake River salmon stocks. The major sections of the report include the following: perspectives on harvest impacts; ocean distribution and in-river adult migration timing; description of management processes and associated fisheries of interest; and alternative harvest strategies.

Of the three populations (or population complexes) of concern to this report (fall chinook, spring-summer chinook, and sockeye), fishing mortality is highest on fall chinook. Current levels of exploitation (on a brood year basis) are estimated to exceed 60% on this population. Snake River fall chinook are caught in all of the major marine mixed stock fisheries between Northern California and Alaska, including within the Columbia River, all of which are targeted on more productive populations.

Impacts by ocean fisheries are much less on Snake River spring-summer chinook and sockeye than on fall chinook. The ocean exploitation rate on spring chinook appears to be less than 5%, though it is likely somewhat higher on summer chinook but less on sockeye. Total exploitation rates (ocean and in-river fisheries combined) on these populations appear to be less than 16% in recent years, with 16% associated with spring chinook and lesser rates for summer chinook and sockeye.

Based simply on the proportion of these populations that are killed by harvesting, the largest potential benefits to recovery that could be gained through harvest measures exist with fall chinook. Harvest measures alone, however, even with complete elimination of fall fishing mortality, would likely be inadequate to achieve a recovered and sustainable population of fall chinook. There is uncertainty in what level of mortality the population can sustain, given the uncertainty in estimates of stock productivity estimates.

Much smaller potential benefits from harvest reductions exist for spring-summer chinook and sockeye than for fall chinook, based solely on the amount of fishing mortality estimated to currently exist on these populations. Elimination of fishing mortality without other remedial actions would be of limited benefit to the populations.

Alternative harvest management strategies exist that theoretically could be implemented to reduce these harvest impacts on Snake River salmon. These strategies include single weak stock management, multiple weak stock management, time-area separation of stocks within fisheries, selective-harvest fisheries, and catch ceiling fisheries. Each varies in feasibility and potential for affecting recovery. Feasibility of at least some of these alternatives is severely limited by the amount of available information on stock distributions and run timing, and on existing capabilities for run size forecasting for chinook salmon.

We have made no attempt to analyze the merits or potential problems with alternative strategies described in the report, other than in a very cursory manner. Serious attempts to implement any of these strategies would require a more comprehensive analysis.

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HARVEST MANAGEMENT AND RECOVERY OF SNAKE RIVER SALMON STOCKS

1.0 INTRODUCTION

Conservation and management of salmon populations entail two fundamental responsibilities. One is protecting the environment that salmon depend on, the other is controlling harvest in order to perpetuate the runs. Recovery plans for Snake River salmon may require special attention to both kinds of management action if a reasonable chance for success is to be gained. Other forms of intervention, such as supplementation and transportation, may be required as well. This report presents information on the potential role of harvest management to recovery.

Pacific salmon populations are highly vulnerable to fishing because of their availability to harvest at one or more stages in their life cycle. Northwest Indians based their livelihoods on the fact that salmon were easily caught while migrating from ‘the ocean to spawning areas. The combined strength of today’s marine and freshwater area fisheries has the capacity to decimate runs if given unrestricted access to harvest (Pearse 1982).

Management measures to regulate harvest have grown increasingly complex over the past decade in response to the needs for improved protection for some runs and more equitable harvest sharing between fisheries (Morishima 1984; PSC 1991). The development of management plans that adequately address both needs is an immensely complicated task; one that involves a multitude of stocks, each with its own migration patterns and capacity to sustain exploitation. The fishing industry that relies on these stocks is also highly diverse. The task is made especially difficult because the stocks are often intermingled on the fishing grounds, creating highly mixed aggregates of stocks and species on which’ the fisheries operate. This situation’is the problem facing harvest managers attempting to protect Snake River salmon.

The purpose of this report is to provide an overview of some of the factors that will need to be considered in assessing the potential for using harvest management measures in the recovery of Snake River salmon stocks. The body of the report is organized into five sections: 1) this introduction; 2) perspectives on ‘harvest impacts to Snake River salmon; 3) a general description of the distribution of the stocks of concern; 4) a description of the fisheries of interest; and 5) a description of some of the possible harvest management strategies that might be considered.

It is beyond the scope of this report to analyze the relative merits and problems of the harvest management measures described in this report (Section 5) and we provide no recommendations on specific measures. We also make no attempt to compare the relative benefits of possible harvest management measures to other recovery actions that could be implemented.

2.0 PERSPECTIVES ON HARVEST IMPACTS

2.1 IMPLICATIONS TO HARVEST PLANNING

Numerous complex issues will need to be addressed in 'attempting to use harvest management measures for recovery of Snake River stocks. These issues involve many biological, legal, political, and economic factors, all of which are considered in formulating annual harvest management **plans** (see Section 4.1). The actions taken in one fishery can affect others because of the movements of fish between fishing areas (Fig. 1). Measures to protect fish in one set of fisheries can be at least partially negated by actions in other fisheries, or 'in the case of Snake River stocks, by losses incurred during upstream migration (Pig. 1).

Implications of harvest measures to protect Snake River stocks extend well **beyond the** Columbia River. Morishima (1993) describes how **efforts** to substantially reduce overall harvest impacts on Snake River salmon could have ramifications to the Pacific Salmon Treaty between the United States and Canada. Depending on how an action was implemented, issues relating to the so-called "'equity principle" of the Treaty could result in other adjustments to fisheries or production. Morishima goes on to point out that in Washington and Oregon various management processes would need to consider an appropriate distribution of **stock-specific** savings between fisheries and escapements.

Some of the many questions that will need to be addressed in devising harvest management measures to assist in recovery include:

- ***How should the burden for recovery be shared between fisheries and other sources of human-induced mortality on the stocks?***
- ***How should the burden for recovery be shared between the many fisheries that harvest Snake River salmon?***
- ***What principles would be used to determine the level of allowable impact of a fishery on a stock of concern?***
- ***How would sharing of the conservation burden be affected by responsibilities and commitments of the Federal Government within the Pacific Salmon Treaty forum and to the various treaties with Northwest Indian tribes regarding fishing?***

To address these questions will require an integrated analysis of the various factors affecting the stocks and the **fisheries** that may be impacting' them, as well as consideration of the many fishery management' processes involved. Our purpose here is not to answer those questions, but to provide information that can assist in doing so.

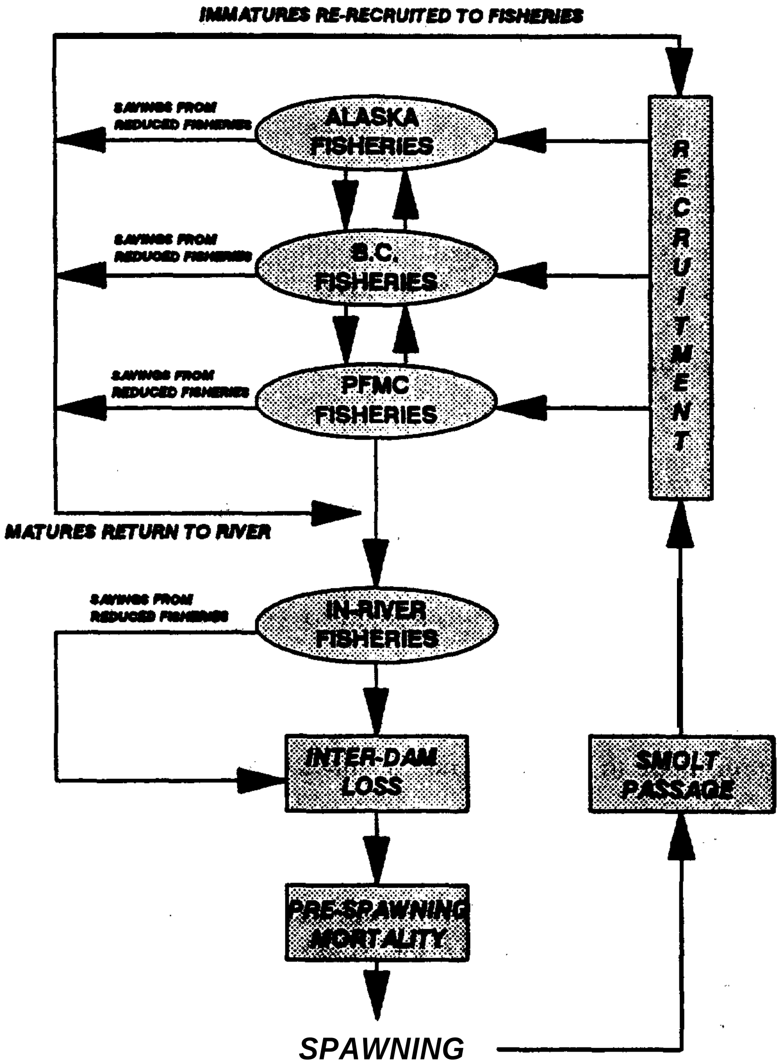

Figure 1. **Pathways of Snake** *River* chinook **"saved"** by **reducing fishery impact.**

2.2 IMPACTS TO FALL CHINOOK

2.2.1 Adult Equivalency Concept

The concept of adult equivalency was developed to standardize comparisons of harvests that occur at different ages and stages of maturity to provide a means of assessing harvest impacts relative to ocean escapement. It was originally used in comparing catches of immature fish in the ocean to those of mature fish in terminal fisheries near the spawning grounds. We apply the concept throughout this report to assess the level of total exploitation that a population can sustain. A basic understanding of the concept is helpful for this discussion. We describe the concept here as it applies to fall chinook because of the emphasis given to fall chinook in this report.

The concept is used commonly in chinook modeling exercises by the Pacific Fisheries Management Council (PFMC) and the Pacific Salmon Commission (PSC) in evaluating exploitation rates. In those forums adult equivalence is defined as the probability that, in the absence of all ocean fishing, fish of a given age will leave the'ocean to spawn. Fish nearing maturity and soon to enter the river are given an adult equivalent (AEQ) value of 1, as are those that have departed the ocean. Immature fish harvested in the. ocean translate into fewer adult equivalents than older fish that are caught.

Equivalent values can also be calculated for locations upstream of the river mouth if significant post-fishery mortality occurs prior to spawning. For example, spawner equivalence would represent the probability that, in the absence of all fishing, fish of a particular age or maturity would arrive at the spawning grounds. The concept used in this manner can be applied to the Columbia River because of potentially significant interdam losses (IDL) that occur upstream of fisheries.

To avoid confusion as to where an AEQ factor is meant to apply, use of adult equivalence in this report refers to the calculation made to the river mbuth, unless specifically stated otherwise.

2.2.1.1 AEQ Factors Calculated To The River Mouth

Adult equivalent estimates for Snake River fall chinook are based on analysis of coded wire tag (CWT) data for Lyons Ferry Hatchery releases, as described by Schaller and Cooney (1992). Only on-station releases of subyearlings are used in the analysis, thus matching the natural outmigration timing of Snake River fall chinook. Brood years 1984-86 are currently incorporated into the calculation *(Mary Ann* Johnson *personal communications)*.

The use of hatchery produced fish to project fishery impacts on wild fish is a common practice in most of the modeling that occurs for ocean fisheries, particularly for chinook (e.g., Schaller and Cooney [Appendix C] 1992; Morishima 1993). Assumptions implicit in this approach are that hatchery and wild fish both have similar oceanic distributions, maturity schedules, and other behavioral patterns that might affect vulnerability to fishing. Healey (1991) notes that the validity of assuming similar ocean distributions between hatchery produced and wild fish remains unresolved, although he found comparable distributions for hatchery and wild fish originating from Vancouver Island. Chapman et al. (1991), in discussing CWT recoveries of Snake River spring-summer chinook, noted that wild fish may be more vulnerable to ocean fishing than hatchery fish because of a tendency for earlier maturity by hatchery fish.

The calculation of AEQ factors incorporates estimates of natural mortality by age and maturation rate (i.e., proportion of ocean fish ready to depart the ocean) (Table 1). Ocean natural survival rates are those that are assumed by the Chinook Technical Committee (CTC) of the PSC for chinook salmon (CTC 1988; Schaller and Cooney 1992). The modeling procedure assumes that natural mortality for a given ocean age occurs prior to fisheries.

The factors represent the proportion of Snake River fall chinook caught at a particular age that would survive to return to the Columbia River in the absence of all ocean fisheries. For example, an estimated 60.8% of fish that are caught at age 2 would return to the Columbia if no ocean fisheries actually occurred. Conversely, 39.2% of age 2 fish (1 - 0.608) would die from non-fishing related causes prior to arriving at the Columbia River. All fish caught at age 5 are assumed would survive to the river mouth in the absence of fishing.

Table 1. Natural ocean survival rates and maturation rates used to calculate adult equivalents for Snake River fall chinook; CWT recoveries of Lyons Ferry Hatchery fish" wen employed in calculating maturation and AEQ rates (adapted from Schaller and Cuoney [1992] with updated factors from G. Morishima [*personal communications*]).

Ocean Age	Ocean Survival	Maturation Rate	Adult Equivalents
2	0.6	0.070	0.608
3	0.7	0.232	0.825
4	0.8	0.659	0.966
5	0.9	1.000	1.000

1/ Lyons Ferry Hatchery subyearling releases, brood years 1984-86.
Tag codes used: BY 84 - 633226, 633227, 633228
BY 85 - 633628, 633639, 633640, 633641, 633642
BY 86 - 634259, 634261.

In addition to catch statistics, adult equivalence can be expressed for fishery exploitation rates. An exploitation rate expressed in adult equivalents represents the AEQ ocean catch divided by the sum of estimated run size returning to the river plus the AEQ ocean catch.[1]

The AEQ factors by themselves cannot be used to assess how many fish would pass to the Columbia River if fisheries are modified or only certain ones are closed. Fish saved from one fishery can be killed in another during the next year of ocean residence or en route to the Columbia River (Fig. 1).

2.2.1.2 AEQ Factors Calculated To Above Lower Granite Dam

Significant non-fishing mortality occurs upstream or within the area of fisheries in the Columbia River. To account for this, AEQ factors can be calculated to points higher in the river system than at the mouth. One procedure for estimating AEQ -factors for fish caught in ocean fisheries but that would be destined to pass Lower Granite Dam in the absence of all fisheries involves simply applying estimated survival rates between dams (dam conversion rates; i.e., 1-interdam loss) to the AEQ factors listed in Table 1 (Table 2).

Two sets of dam conversion rates are given. One set, labeled "Joint Staffs", consist of the values agreed on by the technical staffs of the Washington Department of Fisheries (WDF), Oregon Department of Fish and Wildlife (ODFW), and Columbia River Intertribal Fish Commission (CRITFC). This set is based on Schaller and Cooney (1992) for use in the Snake River fall chinook life cycle model and the PSC chinook model (Morishima 1993). The second set consists of average values (5% loss per dam) obtained. from Chapman et al. (1991) as developed for Snake River spring chinook, but sometimes applied to Snake falls. Chapman et al. (1991) present information indicating that average loss per dam for Snake River fall chinook likely does not exceed 5%. The discrepancy between estimates obtained by the Joint Staffs and Chapman et al. has not been resolved.

The AEQ factors computed to Lower Granite Dam are affected by the rate of dam passage survival. The factors differ for fish caught in ocean and river fisheries.

---

[1] Several different formulations exist for "exploitation rate" depending on how the rate is to be applied. In this report, we generally use the concept of brood year exploitation rate, which considers the cumulative impact of fisheries upon all age classes of the production associated with a single brood year. In several instances for in-river fisheries, we treat the estimated exploitation rate as a calendar year-specific rate, which is done for the sake of simplicity. This use in these instances does not affect the relevant points to be made from the analysis.

Table 2. AEQ factors computed fur Snake River fall chinook to above Lower Granite Dam. ho sets of dam conversion rates are shown representing a range of interdam loss rates.

Ocean Age	Interdam Conversion Rate		AEQ Factors for Fish Caught in			
			Ocean Fisheries		River Fisheries	
	Joint Staffs	5% Loss /Dam	Joint Staffs	5% Loss /Dam	Joint Staffs	5% Loss /Dam
2	0.32	0.66	0.19	0.40	0.32	0.66
3	0.32	0.66	0.26	0.55	0.32	0.66
4	0.32	0.66	0.31	0.65	0.32	0.66
5	0.32	0.66	0.32	0.66	0.32	0.66

The two sets of dam conversion rates applied to Snake River fall chinook differ dramatically and suggest that this may be a critical uncertainty in assessing benefits of harvest reductions. Divergence between the two sets increases in an upstream direction. The average conversion rate for 1986-91 by the Joint Staffs between Bonneville and McNary Dams (0.86) is essentially identical to the result of applying a constant 5% loss per dam (Table 3). Close agreement in this reach, which encompasses the Zone 6 fishery, suggests that disparity between the two estimates of conversion rates is not due to fishery induced losses (killed but not landed and reported) associated with the Zone 6 fishery. The Joint Staffs' estimates in Table 3 also illustrate the amount of interannual variation that may be occurring in IDL.

The two sets of conversion rates diverge substantially beginning at Ice Harbor Dam. Adult fall chinook that pass Ice Harbor Dam are known to fall back below the dam at a high rate (Mendel et al. 1992); radio tagging at that point suggests that substantial numbers of fish passing Ice Harbor may be "dip-ins", produced from other areas in the Columbia basin. Additional studies by Mendel et al. are in progress. However, the Joint Staffs' dam conversion estimate for Ice Harbor Dam to past Lower Granite is derived from expanding the estimates for Lower Monumental to Lower Granite in an attempt to avoid "dip-ins" (Schaller and Cooney 1992). Still, a high rate of fall back is evident for the dams above Ice Harbor, as reported by Mendel et al. (1992). See Dauble (1993) for further discussion on dam conversion rates.

The potential effect of errors in dam conversion on analyzing harvest reductions is discussed further in the following sections.

Table 3. **Comparison** between dam **conversion** estimates for **Snake** River **fall** chinook for **different reaches** of **the** Columbia and Snake **Rivers, 1986-91.**

Source of Estimate	Year	Bonneville to McNary	McNary to Ice Harbor	Ice Harbor to Lower Granite	Bonneville to Lower Granite
Joint Staffs"	86	.95	.86	.38	.31
	87	.85	.86	.44	.32
	88	.92	.84	.35	.27
	89	.86	.86	.45	.33
	90	.79	.88	.60	.42
	91	.75	.82	.38	.23
	Mean	.85	.85	.44	.32
Chapman et al. 1991	all	.86	.95	.85	.66

1/ Source: Columbia River Technical Staffs (1992).

2.2.2 Potential For Increasing Spawning Escapement Through Harvest Reductions

To assess the potential benefits of reducing harvests to spawning escapement requires an understanding of the distribution of mortality after the population becomes vulnerable to fishing. The relationship, or interactions, between the different mortality components must **also** be considered (Fig. 1). Natural mortality in the' ocean is factored out by **expressing catch and** exploitation in adult equivalents.

2.23.1 Distribution of Adult Mortality

One common way of displaying information on adult mortality is with a pie diagram, **each slice** representing the proportion of fish harvested in different fisheries. Such displays **are useful for** gaining an historic snapshot of how a particular mortality slice has compared. in size to others for a given period of time.

Using CWT recoveries for Lyons Ferry Hatchery releases to represent Snake River fall chinook, the average distribution of AEQ mortalities has been described for catch years 1988-1990 (Fig. 2; CTC 1992; **CRITFC** 1993). **A** more detailed presentation of harvest distributions is provided in Section 4.2. The average mortality distribution (Fig. 2) excludes 1991 because of the very few tag recoveries that year; poor smolt survival for the brood producing the predominate age class for 1991 is suspected (Tom Cooney ***personal communications***). The PSC chinook model was used in determining the estimates of AEQ mortalities, which include incidental fishery mortalities (hook&g mortality, etc.) as well as reported catches (CTC 1992).

A limitation of the pie diagram summary is that it cannot be used to interpret how reductions in mortality in one slice might be transferred to spawning escapement. Fish saved from death in one mortality slice may simply be killed in an adjacent slice because of the migrational paths being followed and the sequencing of mortality agents (Fig. 1).

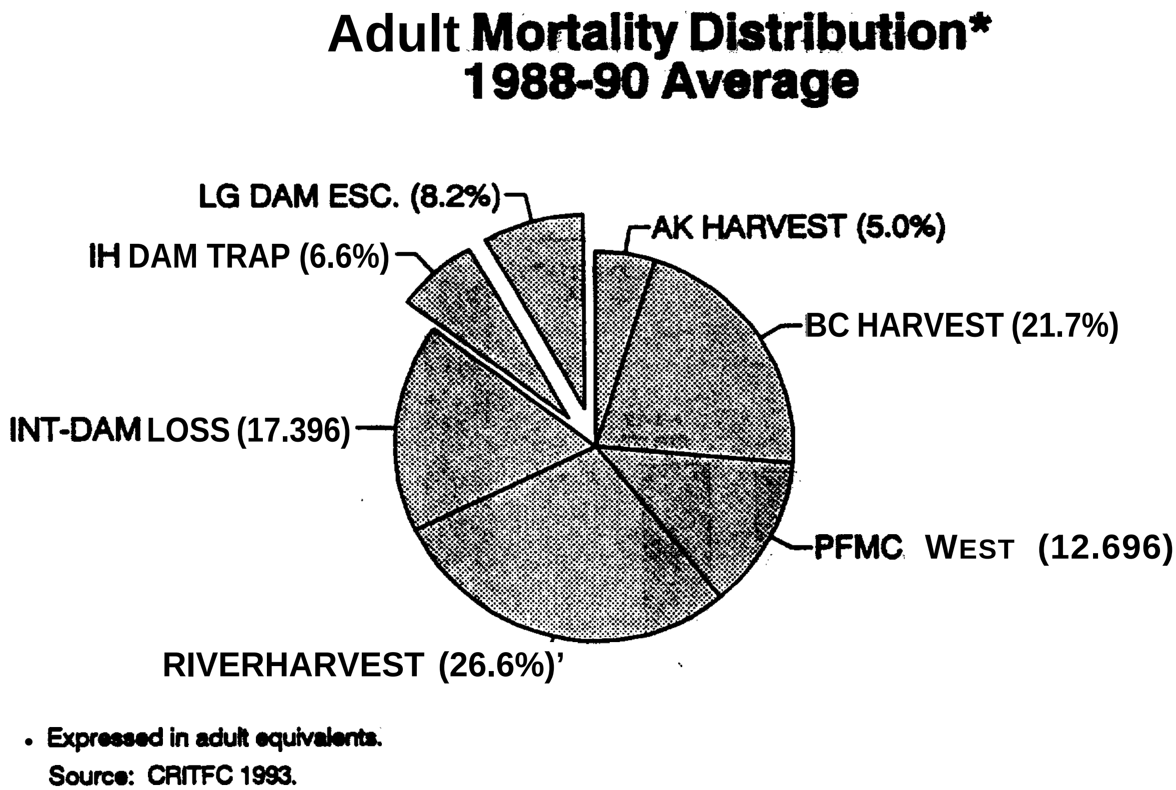

Figure 2. Distribution of adult mortality on Lyons Feny releases of subyearling fall chinook; distribution is assumed to be representative of Snake River wild fall chinook Abbreviations are as follows: AK - Alaska; BC - British Columbia; PFMC - Pacific Fisheries Management Council; INT-DAM LOSS - interdam toss; III DAM TRAP - Ice Harbor Dam Trap; LG DAM ESC - Lower Granite Dam escapement.

The sizes of the slices in Fig. 2 do not operate as mortality rates, and should not be construed as representing the potential for impacting spawning escapement. Thus as fish are removed from the population, mortality in subsequent life stages operates on fewer fish. If you reduce the effect of one source of mortality, then more fish are subject to mortality from other sources. This is best seen by comparing the sizes of slices shown for all ocean fisheries combined, all in-river fisheries combined, and interdam loss. These three amounts add up to 3 9%, 29%, and 17%; respectively. Because fish move through these categories in a sequential manner, mortality rates in each are applied to a steadily shrinking number of fish, resulting in the first slice being the largest and the last one being the smallest

A comparison of average exploitation rates and interdam loss rate presents a different picture (Fig. 3). Estimates of exploitation rate for brood years 1984 to 1986, broken into ocean and in river components, were obtained from CTC (1992) and are based on the PSC chinook model using Lyons Ferry CWT releases as previously d&scribed (Table 4). The rates, expressed in adult equivalents, represent the proportion of fish killed in each category of the total number of fish

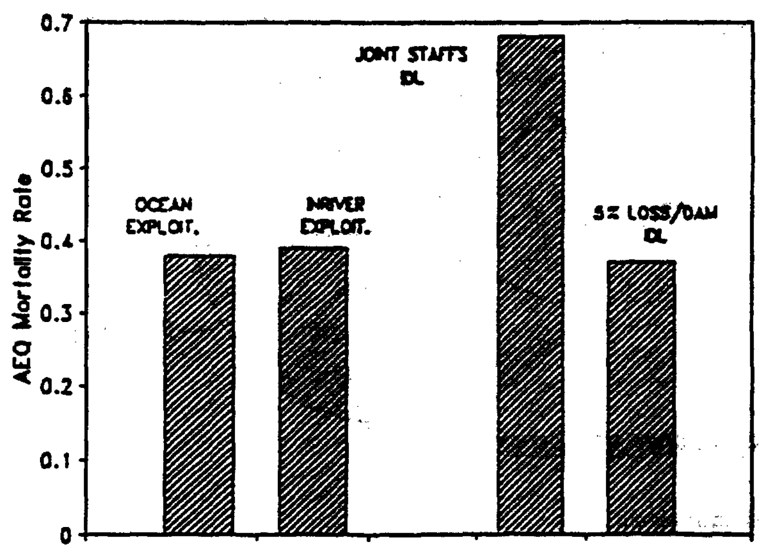

Figure 3. Average AEQ exploitation rates for ocean and in river fisheries and interdam loss (IDL) rates based on two methods of estimation for Snake River wild fall chinook Adapted from CTC 1992.

Table 4. Adult equivalent (AEQ) fishery exploitation rates on Snake River fall chinook salmon.[1] Note: the rates shown represent the proportion of fish killed (lauded and non-landed) of the total number of fish mailable of this stock to the fisheries shown.

Brood Year	Exploitation Rate		
	Ocean	In River	Total
84	0.35	0.38	0.60
85	0.35	0.42	0.62
86	0.45	0.36	0.65
Mean	0.38	0.39	0.62

[1] Source: Chinook Technical Committee (1992).

available in each category. The rates are therefore directly comparable to one another in regards to their potential to affect spawner abundance.The average ocean and in-river exploitation rates are virtually identical for brood years 1984-86 (0.38 and 0.39, respectively). Total AEQ fishing mortality equals or exceeds 60% for each brood year. The two sets of interdam loss rates suggest that mortality rate at this stage is either slightly less than that estimated for marine or river fisheries, or higher than the total fisheries exploitation rate for all fisheries combined. The effect of this uncertainty is examined below.

2.2.2.2 Relationship Between Adult Mortality and Spawning Escapement

A simple, yet illustrative, approach to assessing the potential benefit of reducing the current total fishery exploitation rate is to calculate the expected percentage increase in escapement as exploitation rate is reduced (Fig. 4). The computation is made by simply assuming an AEQ run size and applying the estimated total exploitation rate and estimates of interdam losses.

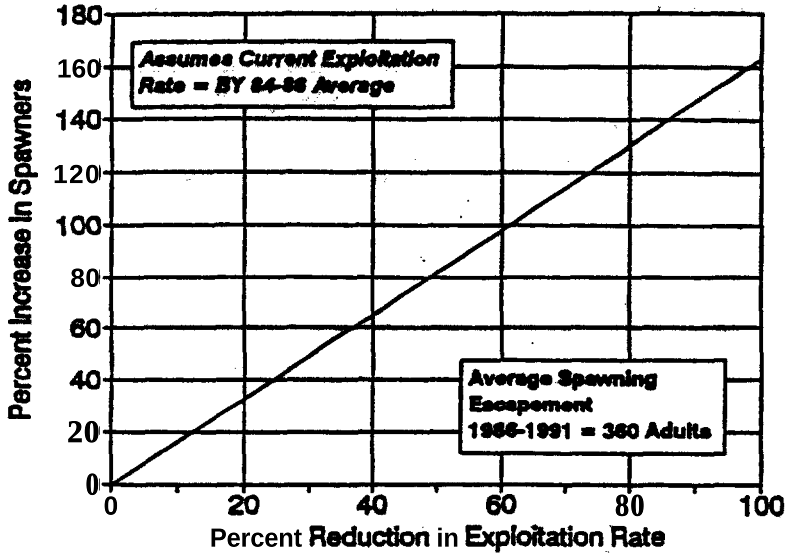

Figure 4. Relationship between percent reduction in current fishery exploitation rate and escapement past Lower Granite Dam for Snake River wild fall chinook. Current exploitation rate is estimated to be 0.62. The escapement of fish from brood years 1984-86 is different than the average value shown for calendar years 1986-91; the latter is shown for simplicity.

The relationship between percent increase in spawners and percent reduction in total exploitation rate is identical for any adult equivalent run size and both sets of interdam 1loss rates. This may not *seem* intuitively logical for the two different sets of interdam loss rates. It occurs' because the interdam loss rate is independent of exploitation rate and operates after the fisheries. (Note: In reality IDL overlaps in area with that part of the fishery that occurs upstream of Bonneville Dam, i.e., the Zone 6 fishery). Thus a proportionate decrease in exploitation rate results in a proportionate increase in spawners, regardless of the added mortality that occurs between the last fishery and Lower Granite Dam. The relationship assumes that only the fishery exploitation rate is being reduced and that the mte of interdam loss is constant and remains unchanged. If actions are taken concurrently to reduce IDL, then a new relationship results. The relationship in Fig. 4 assumes an average IDL rate. In reality, IDL will vary between years due to interannual variation in environmental factors.

The relationship in Fig. 4 should not be construed to mean that IDL is unrelated to escapement. Reductions in IDL will increase escapement. However, which set of interdam loss rates used in the analysis has no effect on an assessment of relative benefits of harvest reductions to spawning, provided that the same set is used in the assessment as used in constructing the run size estimates. Estimates of Snake fall chinook run size reported by the fisheries management agencies (Joint Technical Staffs 1992) are made by using run re-construction methods starting with fish passing Lower Granite Dam and applying dam conversion rates in a downstream direction (Schaller and Cooney 1992). The use of a different set of IDL rates would have resulted in a different set of run size estimates, but the relationship shown in Fig. 4 would be unchanged.

If the estimate of total AEQ exploitation rate in Table 4 is approximately correct, then escapements passing Lower Granite Dam could be expected to increase roughly as follows with reductions in the total fishery exploitation rate as shown:

% Reduction in Exnloit. Rate	Escapement Past Lower Granite[2]	% Increase in Escapement
0	360	0
10	420	17
25	510	42
100	950	167

The analysis is insensitive to assumptions about AEQ run size and interdam losses, but not to the estimated exploitation rate (Fig. 5). The relative benefit to existing levels of spawning escapement of reducing harvest impacts is only affected by the estimate of "current" exploitation rate.

The relationship between reduction in fishery impacts and percent increase in spawning escapement can be modified to incorporate interdam loss rate since the survivals associated with fishing and dam conversion are multiplicative (Fig. 6). Total AEQ mortality rates of 0.7, 0.8 and 0.9 are shown. Use of the exploitation rate derived with the PSC chinook model and the Joint Staffs' interdam loss rate results in an AEQ mortality rate of slightly less than 90%. An IDL of 5% per dam results in a total AEQ mortality rate of 75%.

23.23 Effects Of Altering Harvest Patterns

The difficulty in assessing effects of harvest reductions comes principally in attempting to estimate relative changes in exploitation rate for different fishery patterns. Assessing the effect of changes in ocean fisheries is not trivial because of how savings from reducing selected fisheries can be transferred to other fisheries (Fig. 1).

Morishima (1993) used the PSC chinook model to evaluate three alternative fishery regimes for fisheries that impact Snake River fall chinook, i.e., troll fisheries in Southeast Alaska (SEAR)

[2] Value shown for 0% reduction in exploitation rate is the estimated average for 1987-91 calculated as if broodstock trapping at Ice Harbor Dam had not occurred.

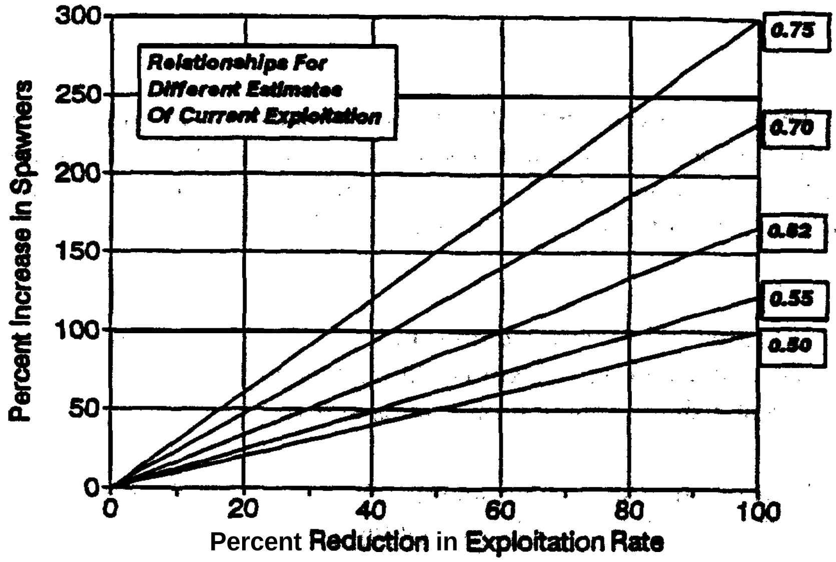

Figure 5. Relationship between percent reduction in current AEQ fishery exploitation rate aud Lower Granite Dam escapement of Snake *River* wild fall chinook for different estimates of existing average exploitation rate. Different values for current exploitation rates are shown along the right side of the graph.

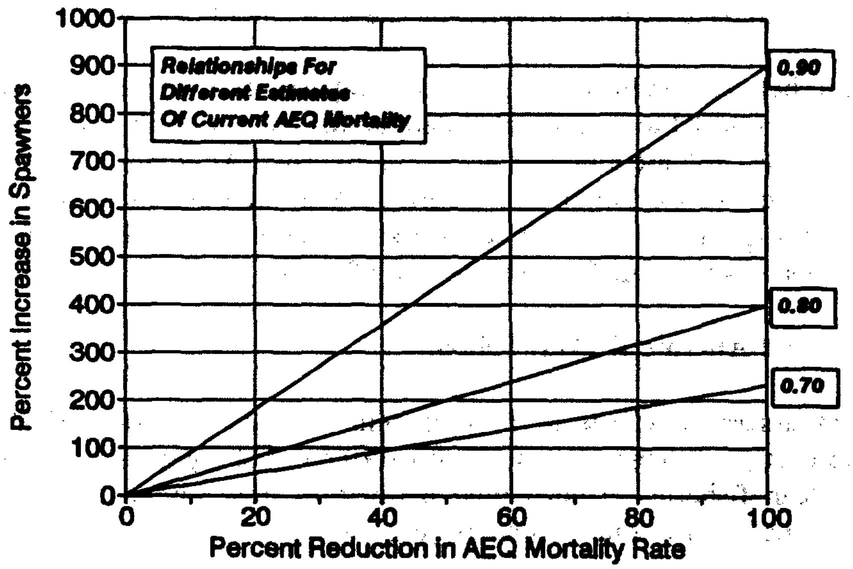

Figure 6. Relationships between percent reduction in current *AEQ* mortality rate (including both fishery and dam related mortalities) and Lower Granite Dam escapement of Snake River wild fall chinook for three estimates of current mortality rate. Values for total AEQ mortality rate are shown along the right side of the graph.

and off the West Coast of Vancouver Island **(WCVI)**. (See Section 4.2 of this report for a description of these fisheries and their relative impact.) The model was used to compare results of modeling 1987-91 actual fishery regimes with those **for** the alternative scenarios' for each year.

The alternative fishery scenarios consisted of much reduced catch ceilings in the SEAR and WCVI troll fisheries but left how all other fisheries were conducted unchanged; including those in the **mainstem** Columbia The alternative scenarios are shown below:

Scenario	SEAK (change from actual)	**WCVI** (change from actual)
A	no change	**- 200,000 fish**
B	**- 200,000** fish	no change
C	**- 200,000** fish	**- 200,000** fish

On the average, these reductions cut approximately 75% and 53% of the actual ceilings in the SEAR and WCVI troll fisheries, respectively (Table 5). Run sizes of Snake River fall chinook returning to the Columbia River mouth were increased for the three scenarios by **16%, 4%,** and 20% respectively (Table 5). Improvements in spawning escapements passing Lower Granite Dam were only slightly different, increases of **15%, 4%,** and 19% were projected. These results indicate that the total fishery exploitation rate on the stock was reduced by a maximum of about **9%, 4%,** and 12% for the three scenarios respectively. In reality, results might differ from those projected because of the rules for managing fisheries in the Columbia River under the Columbia River Fish Management Plan. Those rules could allow for increased fishery harvest rates in the **mainstem** Columbia in response to increasing run sixes.

Modeling results showed that some **of** the fish saved from ocean fisheries were subsequently caught in Washington, mostly in the Columbia River commercial fishery. Catches (commercial and sport combined) of Snake **River fall** chinook in the **Columbia** increased by **20%, 5%,** and **25%** respectively for the three scenarios compared to actual.' Very **little** change occurred in catches of this stock in other Washington 'fisheries.

The modeling results also showed that substantial increases in terminal run sixes occurred for other chinook stocks in the **Pacific** Northwest uniter the three scenarios, with **catches being** adjusted upwards as well.

2.23 Stock Productivity And Sustainable Mortality Rates

The previous sections illustrate how effective harvest reductions **could be in** increasing spawning escapements of Snake River wild fall chinook. The logical question that follows from this is how much of a reduction in exploitation rate would be required to improve the likelihood for recovery.

Table 5. **Estimated changes in catch, terminal run size, and escapement of Snake fall chinook under three alternative ocean fishery regimes for 1987-91. Estimates were made using the PSC chinook model, as reported in Morishima (1993). Modeling results for alternative harvest scenarios (A, B, and C) are compared to those obtained by modeling actual catches for 1987-91 (Actual).**

	Actual	Scenario A	Scenario B	Scenario C
Ave. total SEAK ceiling"	263,000	no change	-200,000[2/]	-200,000[2/]
Ave. WCVI troll ceiling'	376,000	-200,000~	no change	-200,000[2/]
AEQ ocean catch	827	574	765	512
Terminal run	1,891	2,203	1,964	2,277
River catch	618	743	649	774
Escape. past fisheries	1,273	1,459	1,315	1,503
Spawning escape.	385	443	399	458
Increase in spawn. escape.		15%	4%	19%

" Approximate; ceiling is fot total SEAK catch, including troll, net, and sport of which troll is allocated the large majority.

[2/] Change from the year-specific ceiling.

[3/] Approximate.

Productivity, sometimes referred to as the population's intrinsic rate of increase, determines the amount of resilience that the stock has to withstand mortality, or in this case, to man-induced mortality. Stock productivity is related to the density-independent survival rates on the population (or simply, the eggs per female times the survival rate through all life stages when there is no density-dependent effect) (Hilborn and Walters 1992).

Estimates of productivity are obtained through analysis of spawner-recruit (S-R) data; the slope of a S-R curve at very low spawner densities is the estimate of productivity of the population. The estimate is essentially a theoretical limit to how many recruits per spawner areproduced at low spawner densities. Ricker type S-R curves associated with three levels of productivity are illustrated in Fig. 7A. The productivity measure in this case is referred to as the "Ricker A" parameter, shown for values of 1, 2, and 3. A productivity of 1 would provide very little resilience to exploitation.

Productivity is expressed either in terms of the "Ricker A" parameter (Schaller and Cooney 1992; Morishima 1992; Petrosky and Schaller 1993) or alternatively, as the theoretical number of recruits produced per spawner at low stock size, i.e., by what is referred to as the alpha parameter (Reisenbichler 1990). The relationship between "Ricker A" and alpha is shown in Fig. 7B ("Ricker A" is simply the natural log of alpha). We express productivity using the "Ricker A" parameter in this report.

Two estimates of sustainable exploitation rate, or more correctly for our application, adult mortality rate, are obtained directly from estimates of productivity (Ricker 1975): (1) the maximum sustainable exploitation rate and (2) the exploitation rate associated with maximum sustainable yield (Fig. 7C). The first rate is a theoretical maximum limit to how much exploitation a population can sustain; the rate is higher than that associated with maximum sustainable yield. This rate can be thought of as the theoretical limit to the total AEQ mortality rate that can be sustained by the population, which would include in our case both exploitation and IDL. Because this rate theoretically exists only at zero spawner density on a S-R curve, it is not a rate that can be sustained in reality. Still, it provides a maximum boundary to illustrate where true sustainability cannot exist. Thus if AEQ mortality for a population of a given productivity is higher than the theoretical limit to what can be sustained, the population will go to extinction. The second rate is theoretically the exploitation rate that can be maintained to achieve maximum sustainable harvest or yield (MSY).

It should be noted that the productivity parameter is often substantially overestimated for stocks with low productivity (Walters and Ludwig 1981; Reisenbichler 1990). This bias in the procedure to estimate the productivity parameter for stocks of low productivity indicates that caution is warranted in projecting outcomes of management actions on such stocks.

The true limit to sustainable adult mortality, particularly for unproductive stocks, is likely much closer to the MSY exploitation rate than to the theoretical maximum sustainable limit (Fig. 7C). The envelope between the two rates may bracket, therefore, where mortality can be sustained for populations of different productivities, though it is likely closer to the lower curve.

Cramer and Neeley (1993) estimate that productivity for Snake River fall chinook under pristine conditions approached 3.0 (20 AEQ recruits per spawner). Cramer and Neeley conclude that if differences in dam-related mortalities are accounted for, their estimate of Ricker A of 3.0 for Snake fall chinook under pristine conditions is consistent with Schaller and Cooney's (1992) estimated productivity for Hanford Reach fall chinook of about 2.0 (7.2 AEQ recruits per spawner) under present conditions. Cramer and Neeley (1993) attribute the reduced productivity of Hanford Reach fish to increased mortalities due to passage losses.

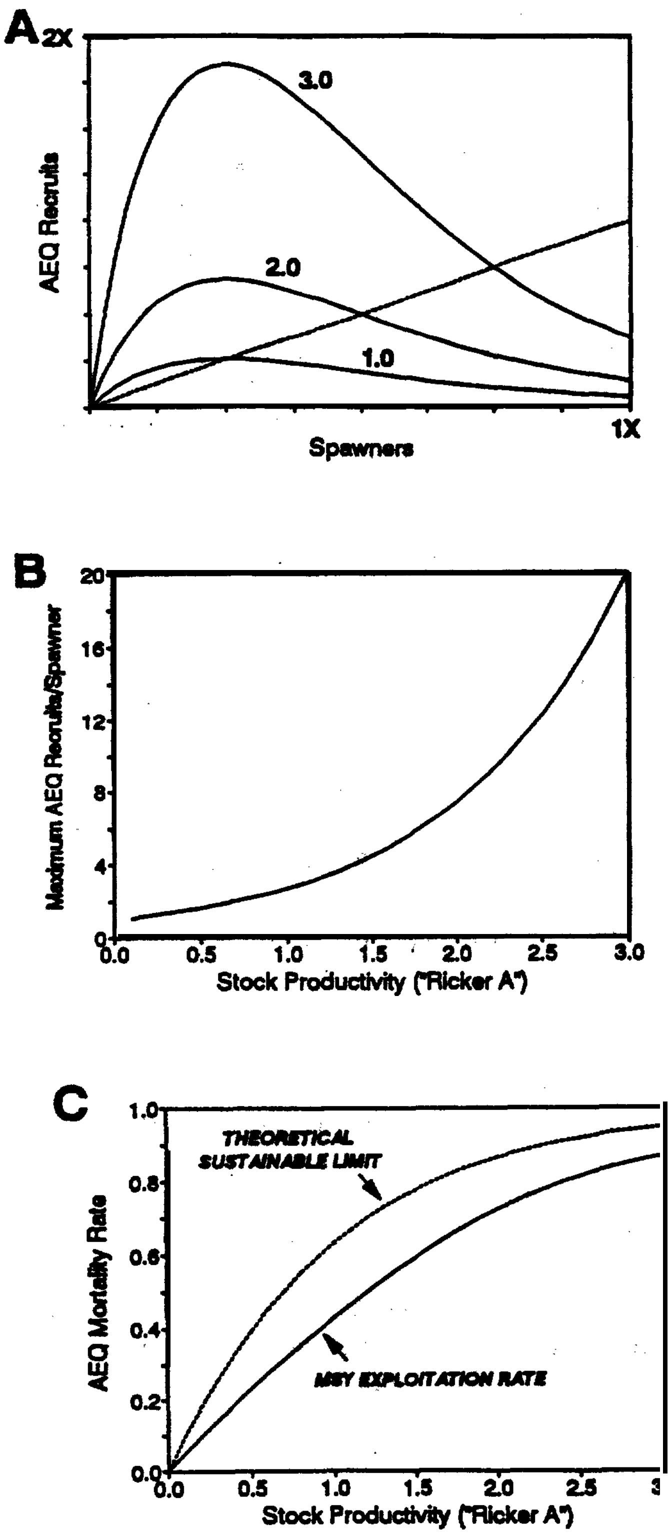

Figure 7. (A) Ricker spawner-recruit curves with productivities ("Ricker A") of 1, 2, and 3; (B) relationship between "Ricker A" productivity parameter values and AEQ recruits per spawner at lower spawner density; (C) the theoretical limit to sustainable AEQ mortality and MSY exploitation rate in relation to stock productivity.

The proportional decrease from the estimated productivity for pristine conditions to that of Hanford Reach provides a basis for approximating what current productivity for Snake fall chinook might be. We assumed that a proportionate decrease in productivity exists between Hanford Reach **fish** and Snake fall chinook under current conditions as estimated between pristine Snake and current Hanford Reach (Fig. 8).

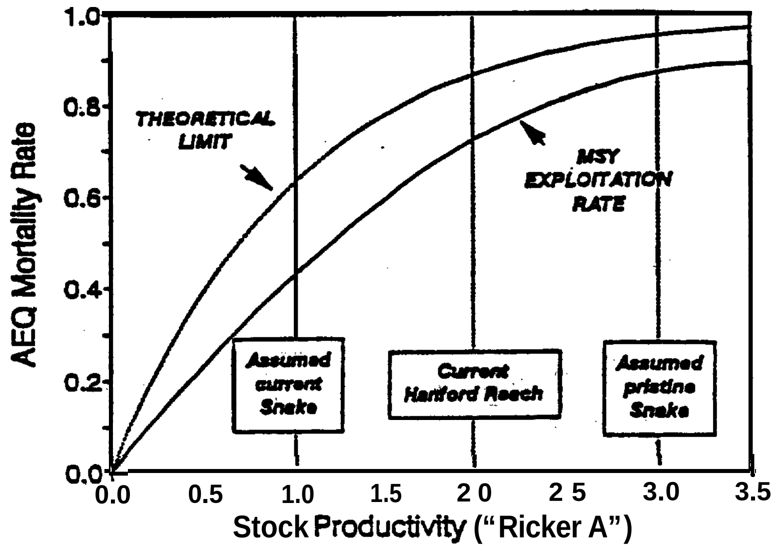

Figure 8. Approximation of historic and current stock productivities for wild fall chinook See text

Such an extrapolation suggests that the current Ricker A value for Snake fall chinook would be about 1.0 (2.7 recruits per spawner). We examined the components of productivity more closely and concluded that current Snake productivity could be lower or higher than this estimate, depending on the assumptions made. Cramer and Neeley (1993) did not present an estimate of current productivity for Snake fall chinook, although their survival rate estimates for different life stages result in an estimated Ricker A value of **roughly 0.6** (I.8 AEQ recruits per spawner), substantially less than our crude approximation of 1.0. It is **logical** to assume that the productivity for Snake fall chinook is considerably less than for Hanford Reach fish given the condition of the Snake stock. Figure 8 provides a basis for considering the level of adult mortality that might be sustainable for Snake fall chinook, where the sustainable mortality rate would be bounded by the two curves in the figure.

To examine the effectiveness of harvest reductions to recovery, we constructed a series of graphs with a range of estimated total **AEQ** mortality shown as horizontal lines (Fig. 9). The lower horizontal line incorporates an **interdam** loss rate of 5% per dam; the upper line utilizes the Joint Staffs' **interdam** loss estimates. Thus each horizontal line depicts the total adult mortality rate resulting from **fishery** impacts and one **of** the IDL **rates**.

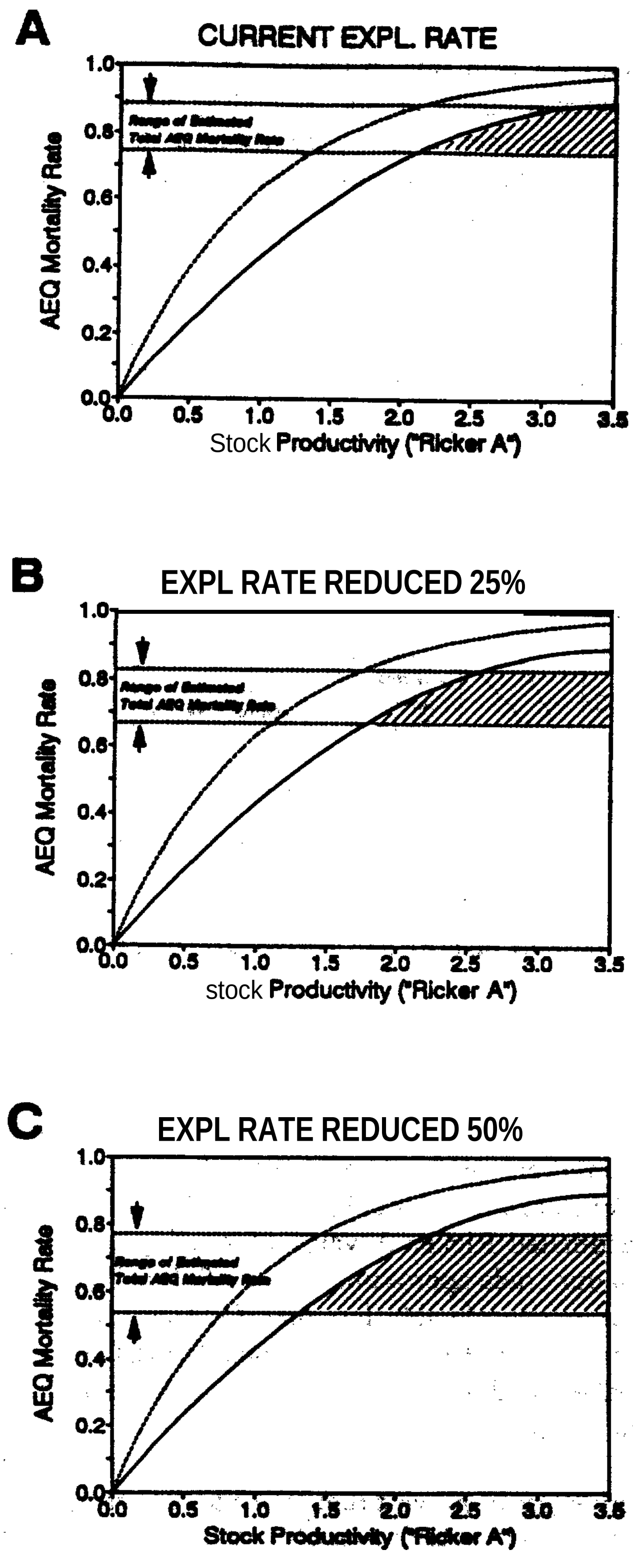

Figure 9(A-C). Estimated **range** of **total AEQ mortality rates** on Saab **River** Wiid **fall chinook in relation** to **estimates** of **sustainable AEQ mortality** for **a range** of **stock productivities.** (A) **current exploitation; (B)** 25% **reduction** in **exploitation; (C)** 50% **reduction** in exploitation.

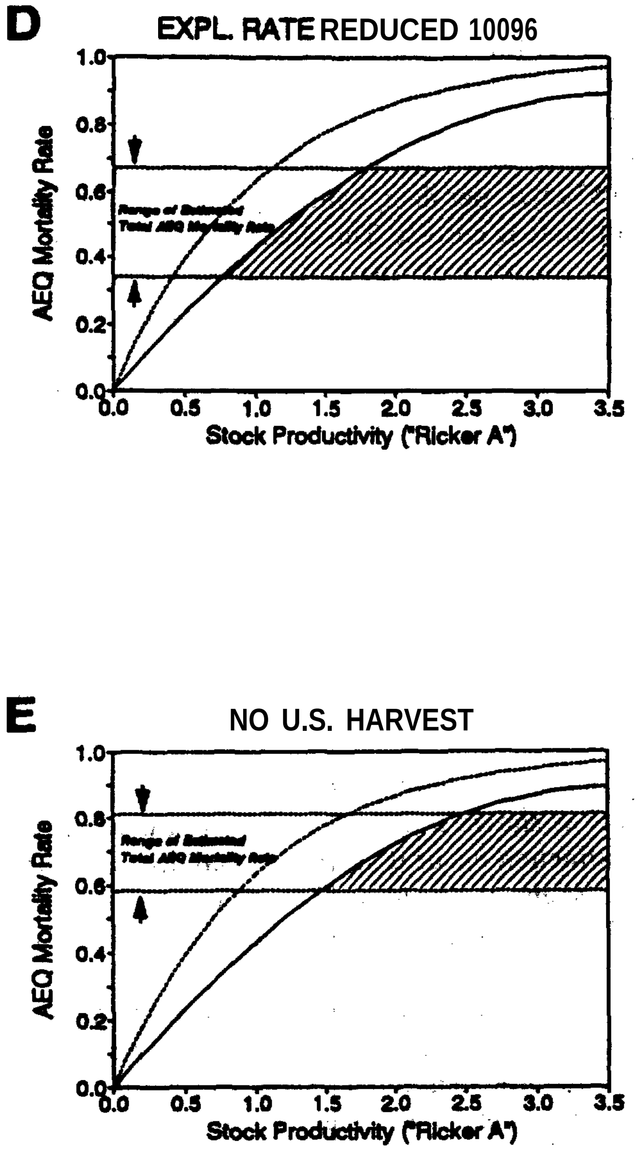

Figure 9(D-E). **Estimated range** of **total** AEQ **mortality rates** on Snake Riverwild **fall** chinook in **relation** to **estimates of sustainable AEQ mortality for** a **range** of **stock productivities. (D) elimination of all** fishery **impacts; (E)** elimination of U.S. **fisheries. See** text

Figure **9A** shows estimated total AEQ mortality associated with the estimated current fishery exploitation rate. The total adult mortality rate is slightly less than 90% with the Joint Staffs' **IDL** estimate and approximately *75%* with a 5% **IDL** rate per dam. The curved lines represent sustainable mortality rates as previously described. Where a horizontal line is higher than the dashed curved line it identifies with a high level of certainty which stocks having a certain level of productivity will go to extinction with that level of adult mortality being applied. As mentioned above, the actual upper boundary to mortality is likely lower than the level represented by the dashed line. So, for example, stock productivities less than about 1.4 would result in extinction with the 5% **IDL** per dam, while a productivity of at least 2.2 would be required if the Joint Staffs' **IDL** estimate is correct The shaded portion of the range of AEQ mortality estimates corresponds to the stock productivities that would with a **high** degree of certainty be sustained with those mortality rates, assuming that the MSY exploitation rate represents a reasonable target for recovery purposes.

Figures **9B-D** provide results for reductions in total fishery exploitation rate of 25% (Fig. **9B),** 50% (Fig. **9C),** and 100% (Fig **9D)**. The total elimination of fishing mortality would appear to be the only case where harvest reductions alone could offer the potential of recovery if **interdam** losses are 5% per dam at a stock productivity of 1.0. At the higher estimates of **interdam** loss, stock recovery would not occur with the total elimination of harvest. Figure **9E** shows AEQ mortality rate estimates if all U.S. fisheries were closed but Canadian harvests were unaffected. We assumed in this case that the Canadian exploitation rate would approximate rates estimated for the 1979-82 base period using the PSC chinook model (estimates obtained from Gary Morishima ***[personal communications]).***

The foregoing may raise a question to the reader: if reducing adult mortality results in increased spawner escapements as shown in Fig. 6, which in. **turn** would result in higher recruitments and so on, why would extinction occur **if stock productivity** is 1.0 or less? The answer is simply that those increases in escapement would not be sufficient in the long run to sustain the population, although there would be immediate but short-term benefits to the population

We conclude from this analysis that harvest reductions alone are inadequate for recovery if current stock productivity is 1.0 or less. To gain even marginal relief through reducing fishery impacts would likely require substantial changes **in current** harvest patterns. Fishery reductions could be used to gain relief in the short-term,. but long-term recovery will likely require reductions in mortality that cannot be realized by harvest management alone. Morishima (1992) presented a similar analysis to the Recovery Team in December 1992 for ranges of estimated juvenile and adult mortalities on the Snake River stock. His conclusions were similar to ours.

2 3 IMPACTS TO SPRING-SUMMER CHINOOK

Available information indicates that ocean exploitation rates on Snake River spring-summer chinook are low, probably less than 5% (Chapman et al. 1991). Similar conclusions about the likelihood for low ocean exploitation rates on these stocks have been reached by the Salmon

Technical Team of the PFMC (PFMC 1992b). The 5% value does not include incidental mortalities, nor is it an AEQ exploitation rate. Incorporation of these factors would likely decrease the estimate, but a 5% rate is assumed for this discussion. Section 3.1 presents a possible explanation for why ocean exploitation rates are so low for thesestocks compared to fall chinook.

The in-river exploitation rate on Snake River spring chinook is estimated to have averaged 12% for 1987-91 (Joint Technical Staffs 1992), slightly higher than the average since 1975 (9.5%). We use an in-river rate of 12% for spring chinook for this discussion. The in-river exploitation rate on Snake River summer chinook is less.

These rates result in an estimated total current exploitation on Snake spring chinook of about 16%, lower than maximum sustainable yield exploitation rates estimated for other spring stocks (Reisenbichler 1990). This estimate provides a basis for estimating potential benefits to the stock that could be achieved by reducing harvest impacts, using the same approach depicted in Figure 5. The approach is not dependent on estimates of dam conversion,

The analysis indicates that a 100% reduction in exploitation rate would increase escapement past Lower Granite Dam by an average of about 20% (Fig. 10). A 50% reduction would increase escapement by about 10%.

We conclude that major reductions in fisheries would be required to gain relatively small increases in spawning escapement.

2.4 IMPACTS TO SOCKEYE

No estimates exist for ocean exploitation rates on Snake River sockeye. The Salmon Technical Team of PFMC has concluded, however, that the probability of harvest on this stock in PFMC fisheries or in the sockeye fisheries of the Strait of Juan de Fuca is very low. (PFMC 1992b).

In-river exploitation in recent years have been very small such that analysis involves estimating the probability of killing one fish. We did not attempt to evaluate those probability estimates.

2 5 EFFECTS OF HARVEST ON POPULATION GENETICS

Harvest does not simply affect the *quantity* of salmon returning to the spawning grounds, it also affects *quality,* i.e., the genetic composition of the surviving stock (Allendorf et al. 1987; Nelson and Soule 1987). Development of harvest regimes to, assist in stock recovery will need to consider how harvest has likely already significantly altered genetic composition and will continue to do so.

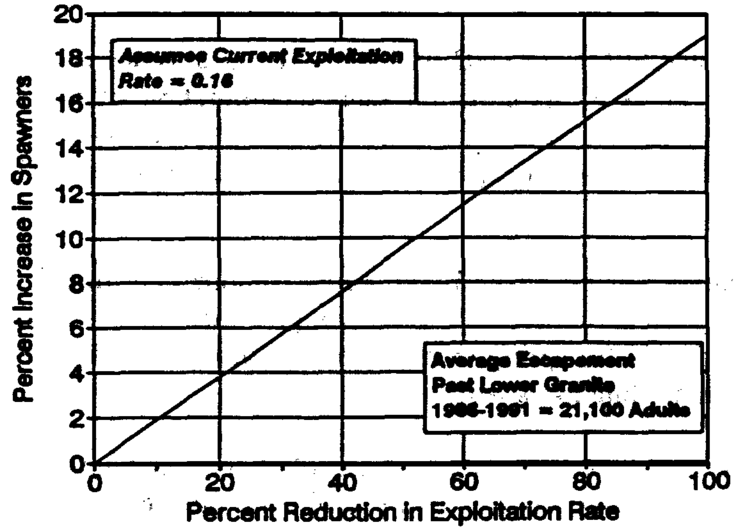

Figure 10. **Relationship between percent reduction in current exploitation rate and escapement past Lower Granite Dam for Snake River spring chinook Current exploitation rate is estimated to average less than 0.16.**

Fisheries can exert strong selective pressures on fish populations due to gear selectivity (for size or sex). In addition, the older age classes of species like chinook are subjected to much higher exploitation rates because of their longer period of vulnerability to fishing. Bicker (1981) describes how the average size of chinook caught in marine fisheries has declined by more than **50%** over the past 50 years; average age of maturity has declined by about two years.

The effects of variable exploitation rates on different ages of chinook salmon. can be illustrated through use of the PSC chinook model. Morishima (1993) presents results of modeling the 1987-91 fishery regimes in the ocean and river for various stocks, ineluding Snake. River wild fall chinook (Table 6). Exploitation rates are much higher on ages four and five fish than on ages two and three fish. ‘By adding the AEQ ocean catches for different ages to the age-specific in-river run sizes, an average age distribution can be estimated for the in-river population in the absence of fishing.[3] The age distribution of the spawning population would be significantly different in that case (Fig. **11**). This dramatic difference in age structure between the fished and unfished populations indicates that productivity per spawner is significantly less in the fed than unfished population. The greater proportion of older fish in the unfished population would have a much higher proportion of females present (females tend to be older) and the females would tend to be larger than those in the fished population. This difference would result in a significantly higher potential egg deposition per adult spawner for the unfished population.

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[3] This procedure is an approximation only; the analysis should actually be done on a brood year basis, which would give slightly different results.

Table 6. Modeling results showing average AEQ ocean catches, in-river run sizes, in-river catches, and escapement for Snake River wild fall chinook, 1987-91; from Morishima (1993).

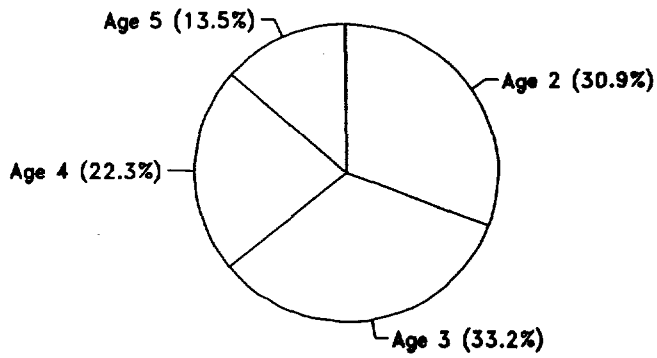
	Age 2	Age 3	Age 4	Age 5	Total
AEQ ocean catch	13	242	408	167	830
In-river run **size**	358	615	662	255	1,891
In-river catch	19	99	390	110	618
Lower Granite escapement	119	128	86	52	385

These results suggest that if a harvest strategy could be devised to increase the average age of spawners from the current condition, then stock productivity could potentially be increased.

Genetic change is also believed to occur by harvesting at a rate that only some components of the stock can sustain, resulting in loss of less productive components and life histories **(Larkin** 1977). Such losses have likely occurred for Snake River stocks.

Changes can occur as a result of disproportionate harvesting on different segments of a salmon run (Nelson and Soule **1987),** as can occur in terminal are&fisheries. For example, if harvest is only allowed on only one segment of a run entering the river, say either the early or late component, then changes can result in the composition of the breeding population.

1987 -9 1 Fishery Regimes



Without Fishing

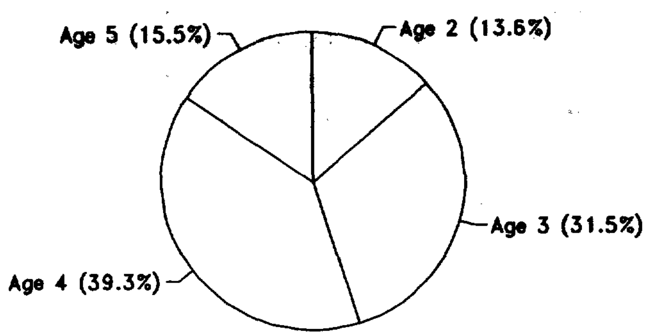


Figure 11. **Estimated average** age **distributions** of Snake River wild fall **chinook based** on **modeling results** for 1987-91 **from Morishima** (1993). Age **distributions are** shown **with** actual fishery **regimes** for 1987-91 **and without any ocean** or **in-river fisheries.**

3.0 GENERAL PATTERNS OF OCEAN AND IN-RIVER ADULT MIGRATIONS

3.1 OCEAN DISTRIBUTION

The ocean distributions for Snake River wild salmon can only be inferred from information available for either hatchery produced fish or from other wild stocks,' No CWT data are available to directly determine distribution for the wild stocks.

North American chinook populations are widely distributed in the Northeastern Pacific Ocean (Fig. 12). The various "streams" of fish illustrated in Fig. 12 originate from the many large rivers along the coast, between Central California and Alaska. There are probably well in excess of a thousand spawning populations of chinook salmon on the North American coast (Atkinson et al. 1967; and Aro and Shepard 1967 cited in Healey 1991). The highly mixed nature of the populations in marine waters is clearly evident from Fig. 12.

3.1.1 Fall Chinook

The distribution of Snake' River fall chinook in marine waters is assumed to be represented by CWT recoveries of Lyons Ferry Hatchery releases as described in Section 2.0. The distribution of Lyons Ferry fish is used for modeling Snake River wild fall chinook in both the Pacific Salmon Treaty and Pacific Fisheries Management Council forums (Schaller and Cooney 1992; CTC 1992). The suitability of using hatchery fish as surrogates of wild fish was discussed in Section 2.0. We believe that it is reasonable to use the Lyons Ferry releases for formulating a generalized pattern of distribution in the ocean for Snake River wild fall chinook.

Estimates of catch composition@ stock have been made for various fisheries along the coast using the PSC chinook model (CTC 1992; Gary Morishima *personal communications).* We used those results to estimate catches of Snake fall chinook per 1,000 total chinook landed in various fisheries (see Section 4.2). The averages for 1987-91 provide a very general pattern of the distribution and abundance for this stock relative to the total for others (Fig. 13). This stock appears to be caught in all of the major mixed stock fisheries from Northern California to Southeast Alaska.

The primary direction of movement from the Columbia River appears to be northward, though CWT analysis indicates that a substantial number of fish move south also. The percentage of the population that move north and south cannot be inferred from Fig. 13 because the relative abundance of other stocks is also incorporated into the graphic. Fall chinook from the Snake River apparently have a tendency to move south of the Columbia in a higher proportion than other upper Columbia River fall chinook (Waples et al. 1991). The catch concentration shown for south of Cape Falcon (near Astoria) includes the entire ocean catch of chinook to the limit of their range in southern California; concentration values computed for waters off Oregon alone would be higher than shown while concentration off California would be lower.

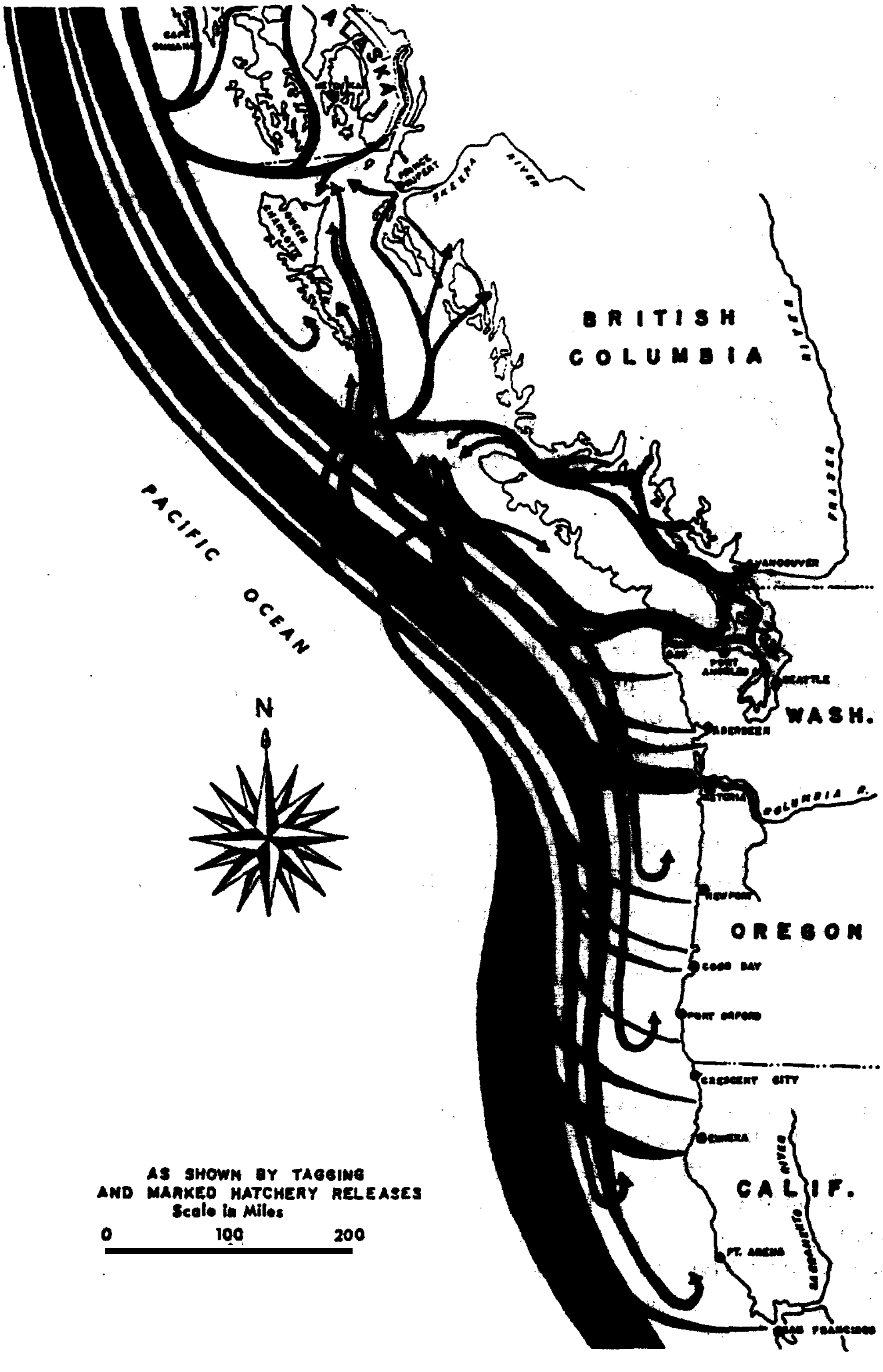


Figure 12. **Migration patterns** of chinook salmon. *Adapted from WDF (1975).*

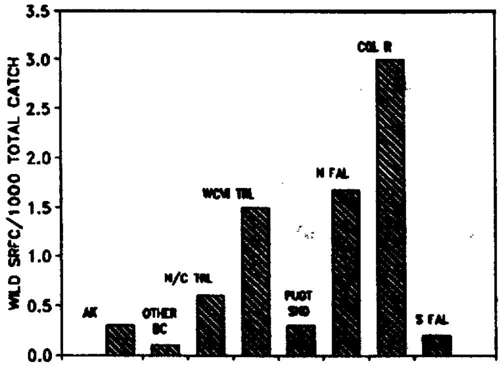


Figure 13. **Estimated average** catches of Snake River **fall** chinook per **1,000 total chinook landed** in **salmon fisheries** between **California and** Alaska, **based** on catch **years** 1987-91. **Abbreviations are:** AK- **Alaska;** N/C TRL - **north** and **central** BC **coastal troll;** WCVI TRL - West Coast Vancouver **Island troll; PUGT** SND - **Puget Sound;** N FAL - **north** of Cape **Falcon;** COL R - Columbia **River;** S FAL - **south** of Cape **Falcon.** Catch **concentrations** of Snake **fall** chinook **in** the **Columbia** River **were** computed **with total catches** of fall chinook **only; spring chinook were** excluded.

3.1.2 <u>Spring-Summer Chinook</u>

Coded wire tag recoveries for hatchery spring and **summer** chinook produced in the Snake River are not considered adequate to model their ocean distributions due to few tag recoveries **(Gary Morishima** ***personal communications*).** Of 2.8 million tagged hatchery Snake River spring chinook released from Rapid River and Sawtooth hatcheries from the 1976 to 1987 brood years, only **four** observed recoveries were made in marine fisheries **(PFMC** 1992b). Over 600 tag recoveries were observed for in-river fisheries and spawning **escapement.** Results of GSI analysis indicate **a** similar low contribution of these fish to marine fisheries **(PFMC** 1992b).

A somewhat higher proportion of Snake River summer chinook appears to occur **in marine** fishery areas than for Snake spring chinook, though **CWT** data are considered **inadequate** to model distribution **(PFMC** 1992b; Gary **Morishima** ***personal communications*).** Still, it appears that Snake River summer chinook are much less available to being harvested by marine fisheries than are Snake fall chinook (Berkson 1991; **PFMC 1992b; NMFS** 1992).

Reasons for the general lack of harvest of Snake River spring and summer chinook in the ocean can only be speculated on; it appears, however, to be related to migrational behavior that avoids the times or areas of heavy fishing. Healey **(1991),** in summarizing information on ocean distribution of chinook salmon, provides a plausible explanation. Healey **summarized** the available information on ocean migrations of ocean-type (0 age smolts) and stream-type (yearling smolts) chinook salmon. Snake River fall chinook are ocean-type while Snake spring and summer chinook are both stream-type (Matthews and Waples 1991). Healey reports that available information indicates that stream-type chinook move offshore early in their ocean life, whereas ocean type chinook remain more closely associated with coastal waters (based on Healey 1980a and 1980b, Healey 1983, Miller et al. 1983, Fisher et al. 1983 and 1984, and Hartt and Dell 1986).

Stream-type fish appear to maintain a more offshore distribution throughout their ocean life than do ocean-type (Healey 1991). Although ocean-type fish are captured offshore in the eastern half of the North Pacific Ocean, they are much less common there than stream-type fish, whereas the reverse is true close to the coast. In those areas, for example, stream-type fish make up a relatively small proportion of the ocean troll catch, generally less than 20%, and significantly less than one would expect from the proportion of stream-type fish in the regional spawning populations (Healey 1991). Healey interprets these patterns to mean that maturing stream-type fish move rather quickly through the coastal marine fisheries to the river estuaries and so are available for only a short time to harvest by ocean troll and sport fisheries which operate relatively close to the coasts.

If these patterns are representative of Snake River ocean-type and stream-type fish, it would explain why Snake spring and summer chinook are subjected to low ocean harvest rates compared to Snake fall chinook.

If Snake River spring-summer chinook migrate further west in the ocean than do fall chinook, it might make the former more susceptible to harvest in high seas fisheries, as postulated by Chapman et al. (1991). Recoveries of CWT spring-summer chinook in those fisheries, however, is not higher than occurs in the coastal troll and sport fisheries (Gary Morishima *personal corn m unications).*

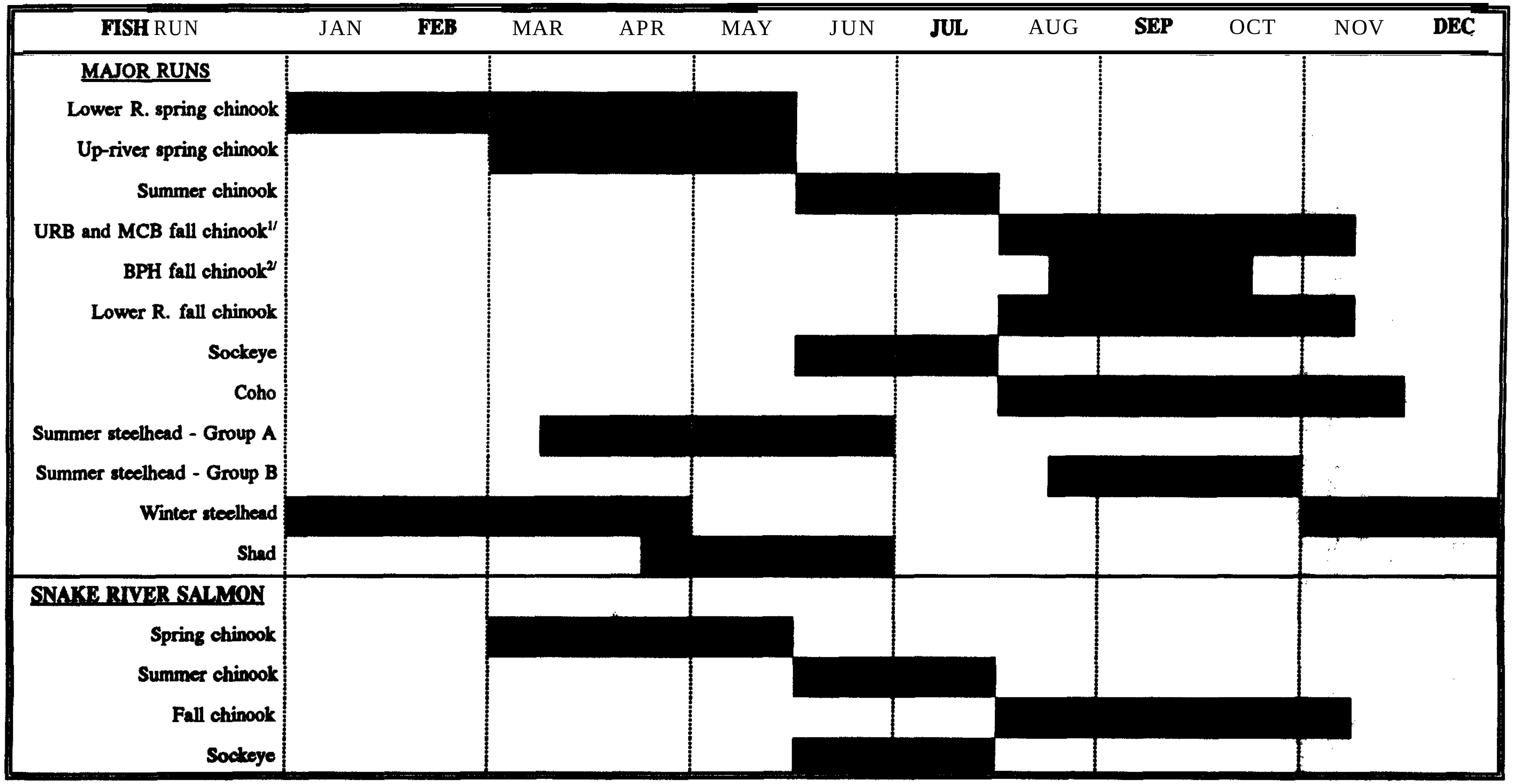
3.13 Sockeye

No information is available on the ocean migration and distribution of Snake River sockeye. Burgner (1991) summarized available information on the ocean distributions of North American sockeye and suggests that there may be considerable overlap in migratory distributions of fish originating from streams between the Alaskan Peninsula and the Columbia River. The principal ocean feeding area is in the far northeastern portion of the Pacific Ocean and within the Gulf of Alaska. Stocks originating from central Alaska, however, appear to migrate much further to the west than fish produced in Southeast Alaska, British Columbia and Washington (based on French et al. 1976), likely making the more northern stocks more susceptible to Japanese high seas fisheries.

The return migration of Snake River sockeye from their ocean feeding grounds to the Columbia River likely occurs prior to the major fisheries in the Strait of Juan de Fuca that harvest sockeye destined for the Fraser River and Puget Sound (PFMC 1992b), thereby avoiding those fisheries.

3.2 IN-RIVER ADULT MIGRATIONS

Adult salmon and steelhead enter the Columbia River from the Pacific Ocean every month of the year (Figure 14). The high degree of overlap in timing between many of the runs illustrates the mixed-stock nature of fisheries in the mainstem Columbia. Patterns of upstream migration for Snake River salmon are belie&&i to be nearly identical to other runs destined for other areas of the basin.



[1/] URB - Up-river bright; MCB - Mid-Columbia bright.
[2/] BPH - Bonneville Pool Hatchery

Figure 14. **Average timing of adult** salmon, **steelhead,** and shad **through** the lower Columbia River. **Source: WDF/ODFW (1992).**

4.0 DESCRIPTION OF EXISTING FISHERIES

This section provides an overview of the major fishery planning processes that can affect Snake River salmon, followed by descriptions of each of the major fisheries of interest

4.1 OVERVIEW OF FISHERIES MANAGEMENT PROCESSES

The extensive migrations of Snake River chinook during their life cycle subject these stocks to harvest by numerous fisheries between Northern California and Alaska as well as on the high seas. These fisheries are targeted on healthier fish stocks but catch substantial numbers of co-mingled weaker stocks.

During these migrations, which may extend for thousands of miles, Snake River chinook cross many jurisdictional boundaries, some of which are shown in Fig. 15 No less than twenty different entities that manage salmon fisheries can have a direct impact on Snake River fall chinook; these include:

- The Pacific Fisheries Management Council in the three to 200 mile Fisheries Conservation Zone off California, Oregon, and Washington;
- The States of Washington, Oregon, Idaho, and California within their respective territorial waters;
- The State of Alaska within its coastal waters;
- The Canadian Department of Fisheries and Oceans for the O-200 mile zone off the coast of British Columbia;
- Various Indian tribes that fish in the ocean, Strait of Juan de Fuca and Puget Sound (some of the major ones being the Quinault, Hoh, Quileute. Makah, Klallam bands, Tullalip, Swinomish and Lummi);
- Columbia River tribes that are party to the Columbia River Fish Management Plan (Umatilla, Yakima, Nez Perce, and Warm Springs);

The list is larger if all entities that manage fisheries, including non-salmon species, are added. The above list does not include the Pacific Salmon Commission because it is not a management entity, nor the North Pacific Fisheries Management Council. The latter defers in matters regarding salmon in Southeast Alaska to decisions that result from the Pacific Salmon Treaty and to the Alaska Board of Fisheries, though it maintains jurisdiction beyond three miles from the Alaska Coast.)

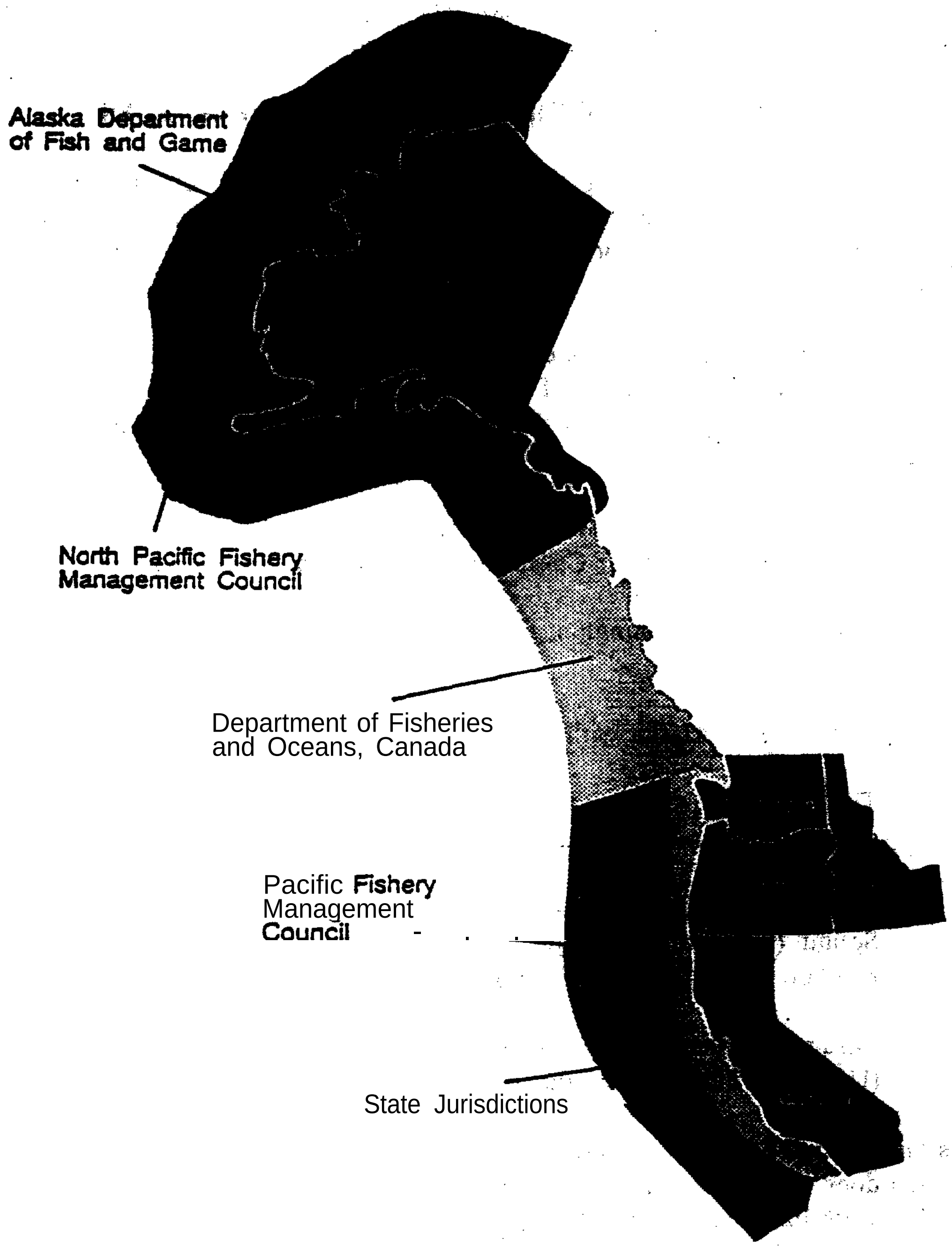


Figure 15. **Major management jurisdictions within the Pacific Ocean and Bering Sea.**

Numerous management policies, processes, and legal factors are involved in developing and regulating these fisheries. These include the Pacific Salmon Treaty between the United States and Canada, various treaties between the United States and different Indian tribes, and management principles described through federal court actions, such as those in U.S. vs. ***Washington, U.S. vs. Oregon,*** and ***Hoh et al.*** vs. ***Baldrige***. The complexities and interactions between these issues create a management maze in which harvest impacts to Snake River salmon occur.

The overlapping and diverse management systems that regulate these fisheries as they relate to Columbia River stocks can be simplified into a **hierarchial** framework (Fig. 16). The **major** components of the framework are described in the following sections.

4.1.1 Pacific Salmon Treaty

The Pacific Salmon Treaty between the United States and Canada, which became effective in March 1985, has a potentially significant effect **on some** Columbia River chinook runs **because** of the limits it imposes on Canadian and Alaskan interceptions. The Treaty established harvest ceilings for chinook salmon for certain Canadian and Alaskan fisheries-in response to a **coastwide** program to rebuild depressed natural stocks of chinook salmon. Ceilings in these fisheries affect all chinook stocks that utilize those areas, including far-north migrating chinook stocks, such as Snake River fall chinook.

Fisheries harvesting chinook incidental to other species, and near-terminal and terminal chinook fisheries not included in Treaty ceilings, were to be managed under **a** Treaty "pass-through provision. Both counties agreed to manage all salmon fisheries in Alaska, British Columbia, Washington, and Oregon, so that the bulk of **depressed** stocks preserved by, the program accrued principally to spawning escapement.

Four major fisheries, or fishery complexes, were placed under Treaty chinook catch ceilings, Southeast Alaska all gear, North/Central (N/C) British Columbia all gear, West Coast Vancouver Island **(WCVI)** troll, and Georgia Strait sport and troll. Base catch, **ceilings** for 1985-89 were approximately 263,000 for each of **S.E.** Alaska and N/C **British** Columbia, **360,000** for **WCVI** troll and 275,000 for Georgia Strait sport 'and troll. In 1990, base **catch** ceilings **for** both S.E. Alaska and N/C British Columbia were increased by 15% **(PSC** 1991). In **1991,** ceilings in the S.E. Alaska and N/C British Columbia fisheries reverted back to pm-1990 levels.

The Treaty established the Pacific Salmon Commission **(PSC)** for **implementing its** provisions. The PSC consists of policy and technical representatives from both countries.. **Provisions** of the Treaty, which include the setting of harvest ceilings in fisheries of concern, are periodically negotiated by the PSC members, then sent as recommendations to the **federal governments** (State Department for the United States). These provisions essentially determine how harvests are to be allocated between the countries and conditions for those harvests.

United States-Canada Pacific Salmon Treaty
International agreement that provides a framework for management of salmon stocks taken in Canadian and U.S. fisheries, including Columbia River stocks.

Pacific Fisheries Management Council
Regulates marine salmon fisheries in U.S. territorial waters adjacent to the states of Washington, Oregon and California from three to 200 miles offshore.

Columbia River Management Plan
(United States vs. Oregon)
Provides legal framework for allocating treaty Indian and non-Indian fisheries for salmon runs in upper Columbia River Basin.

Ocean and In-river Agreement
Part of the United States vs. Oregon process, the agreement describes the harvest of Columbia River fall chinook between marine and in-river treaty Indian and non-Indian fisheries.

Columbia River Compact
Interstate body involving the states of Oregon and Washington that regulates treaty and non-treaty commercial fisheries on the interstate portion of the Columbia River where it forms the boundary between Washington and Oregon Created by an act of Congress in 1918.

State Agencies
(Have jurisdiction over marine fisheries within the three-mile limit and freshwater fisheries within state boundaries, except for Indian reservations, certain treaty tribal fisheries and national parks.)

Oregon Department of Fish and Wildlife

Washington Department of Fisheries

Washington Department of Wildlife

Idaho Department of Fish and Game

Tribes
(Have jurisdiction within reservation boundaries and over tribal members conducting commercial, and ceremonial and subsistence fisheries.)

Parties to U.S. vs. Oregon
Yakima
Umatilla
Warm Springs
Nez Perce
Shoshone-Bannock

Non-parties
Colville *(status to be determined)*

Figure 16. Regulatory framework for major fisheries affecting Columbia River salmon and steelhead stocks. *Reprinted from Integrated System Plan (CBFWA 1991).*

Once fishery conditions and ceilings are agreed to, each country implements appropriate actions to manage its fisheries (non-chinook fisheries targeted on certain Fraser River stocks are treated somewhat differently).

Prior to adoption of the Pacific Salmon Treaty, the North Pacific Fisheries Management Council (NPFMC) was responsible for setting catch quotas in waters north of the Canadian border, in a manner similar to the process followed by the PFMC (see Section 4.12). NPFMC now defers to the PSC process for establishment of catch ceilings and to the Alaska Board of Fisheries for allocating the ceiling for Southeast Alaska between the commercial and sport fisheries (see Section 4.2.1.2).

The Chinook Technical Committee (CTC) of the PSC recently reported that the rebuilding response of the spawning escapement indicator stocks is inconsistent with expectations (CTC 1992). There has been a general decline in the proportion of stocks that are classified as rebuilding, while the proportion of stocks that are not rebuilding has increased. The CTC (1992) stated that projections for continued poor survival of certain runs, mentioning some upriver Columbia runs, indicate that results of reducing exploitation rates will be less than originally required to achieve rebuilding.

4.1.2 Pacific Fishery Management Council

The Pacific Fishery Management Council **(PFMC)** is a federal entity responsible **for** establishing harvest levels within 3 to 200 miles off the coasts of California, Oregon and **Washington.** Fisheries inside 3 miles are under the jurisdictions of the states and treaty **tribes** and are **designed** to be consistent with PFMC management plans. Off Washington, coastal treaty Indian tribes exercise jurisdiction over their troll fisheries. All salmon fisheries within three **miles of** the **coast** are integrated into the annual plan for all coastal waters. The **PFMC** gains its authority **from the** Magnuson Fishery Conservation **and Management Act. The Council's members include officials** from the fisheries agencies of the four states (including Idaho), the Federal **government,** Northwest Indian tribes, and industry.

Each year the Council submits its recommendations for fishery regimes for the coming season to the Secretary of Commerce for final adoption. The regimes are developed **under** the Co**uncil's** Framework Management Plan, a multi-year management plan that describes the processes by which the fisheries will be managed During the course of formulating the fishery regimes for the coming season, state and tribal representatives meet to discuss **how** the harvest is **to** be **shared** between ocean and other fisheries not under the jurisdiction of **PFMC.** Thus the fisheries in each of the two areas (outside and inside 3 miles) are planned so that the effects of the collective fisheries are considered, both for allocation and conservation needs.

As a result of litigation in 1982 ***(Hoh et al. vs. Baldrige)*****, PFMC** is required **to** establish fishery regulations that return sufficient harvestable fish to terminal areas for treaty tribes on **a** run by run basis, while providing for conversation needs Prior to this time, the Coundl sought to **satisfy** treaty Indian allocation requirements by aggregating across many rivers and runs. The change in

1982 resulted in what has now come to be known as "weak stock" management, **i.e.,** managing for allocation and conservation needs in the ocean on the basis of the weakest stock of salmon.

PFMC manages the ocean chinook fisheries in four primary units, with each having a different emphasis on stocks of concern:

1) ***U.S./Canada border to Cape Falcon -*** area extends to south of Astoria, primary stocks of concern are Columbia River fall chinook;

2) ***Cape Falcon to Humbug Mountain -*** area extends to southern Oregon, primary stocks of concern are Oregon coastal chinook and Klamath fall chinook;

3) ***Humbug Mountain to Horse Mountain -*** area extends to an area south of the Klamath River in Northern California, the primary stock of concern is Klamath fall chinook;

4) ***Horse Mountain to U.S./Mexico border -*** primary stocks of concern are Central Valley chinook, of which Sacramento winter-run chinook are listed as threatened under the ESA.

PFMC sets area-specific harvest quotas for chinook based on objectives and stock status for each area. Separate quotas are established for treaty Indian and non-treaty fisheries north of Cape Falcon. Allocation of the non-treaty share between the troll and recreational fisheries is based on formulas contained in the Framework Management Plan and **inter-port** sharing agreements.

The PFMC must also consider implications of the listing of salmon stocks under the Endangered Species Act **(ESA),** and terms of the U.S./Canada Pacific Salmon Treaty in its formulation of management approaches and regulations for the **salmon** fisheries. The **Council's** proposed **plans** and regulations for each season are reviewed and an assessment of **impacts** is prepared **for** those salmon stocks listed as endangered or threatened under the **ESA.** These assessments are **part of** the process leading to formal adoption of the annual regulatory measures **(PFMC** 1992b).

No direct management measures for chinook salmon within PFMC were specified in the **Pacific** Salmon Treaty except for a commitment to ensure that the bulk of depressed naturally spawning chinook stocks, saved as a result of PSC harvest ceilings, accrue **principally to** escapement. The **PFMC's** ocean fisheries on depressed stocks are designed to minimize impacts on **spawning** escapements of these depressed stocks **(PFMC** 1993a).

4.1.3 Columbia River Fish Management Plan

Columbia River fisheries are managed according to the Columbia River Fish Management Plan (CKFMP), adopted by the U.S. District Court in 1988. This plan is the successor to a similar one implemented in the late 1970s called the Columbia **River** Five-Year Plan. The **CRFMP** was developed by the parties to U.S. vs. Oregon to provide a framework within which the parties may exercise their rights to conduct fisheries in a coordinated and systematic manner, while protecting and rebuilding upper Columbia River fish runs. Terms for run rebuilding, allocation and operation of the fisheries are defined by the plan. The CRFMP is at least partly founded upon chinook rebuilding, though not aimed at Snake River fall chinook, and harvest sharing principles set forth in the Pacific Salmon Treaty. Parties to the plan are Oregon and Washington and the Yakima, Umatilla, Warm Springs and Nez Perce tribes. Unless renewed, the plan will expire no later than December 31, 1998.

The CRFMP establishes a Technical Advisory Committee (TAC), Production Advisory Committee (PAC) and a Policy Committee to perform various tasks of implementing the plan.

The Columbia River Compact, an interstate body comprised of Oregon and Washington, is responsible for establishing the regulations for the fisheries associated with the CRFMP. The states have jurisdiction over implementing the regulations for their respective fishers. The tribes have jurisdiction within the boundaries of their reservations and over tribal members fishing off' reservation.

4.1.4 Ocean and In-river Agreements

As noted above, representatives for the Indian tribes and the States of Washington and Oregon seek agreement on upcoming terminal area fisheries prior to formal agreement on ocean fisheries by the PFMC. This step in the management process acknowledges the linkage between fisheries and the effect of one on the other (Fig. 1). This process is sometimes referred to as the "North of Cape Falcon Fisheries Planning Meetings." Separate agreements are made between the states and individual tribes for the various rivers or fisheries of interest. A similar process exists for fisheries south of Cape Falcon that involves the tribes in the Rlamath area.

4.1.5 Other Relevant Management Forums

Several other forums exist for managing fisheries not directly tied to the salmon management process shown in Fig. 16. These are only briefly mentioned here.

Fisheries targeted on other species besides salmon off the coasts of California, Oregon and Washington are managed by PFMC (Fig. 15). A management plan is prepared each year by that council for the harvests of species of interest. A similar plan is prepared by the North Pacific Fisheries Management Council for the management of groundfish beyond 3 miles off the coasts of Alaska (Fig. 15). Groundfish fisheries can affect salmon stocks through their by-catch (incidental catches).

A new management entity has recently been established called the North Pacific Anadromous Fish Commission (NPAFC). The NPAFC, which came into existence on February 16 of this year, replaces another commission that has ended called the International North Pacific Fisheries Commission (INPFC). The NPAFC consists of four member countries: United States, Canada, Japan, and Russia The NPAFC is the product of the Convention for the Conservation of

Anadromous Stocks in the North Pacific Ocean. The Convention prohibits salmon fisheries on the high seas by member countries and is to help minimize incidental salmon catches by high seas fisheries directed at non-salmon species. The ban on high seas salmon fishing could provide some relief to Columbia River salmon and steelhead, though it is likely to of minor consequence to Snake River stocks (based on information presented in Morishima [1993]).

4.2 THE FISHERIES

The primary fisheries of interest to the stocks of concern are described in the following text, together with a general assessment of their potential impact on Snake River stocks. The emphasis for marine fisheries is placed on chinook salmon fisheries.

Annual harvest distributions of Snake River fall chinook have been relatively consistent between fisheries in recent years, with the exception of 1991 (Fig. 17), assuming that Lyons Ferry Hatchery releases of tagged subyearlings are representative of wild fish catch distribution (see Section 2.1.1.1). Differences exhibited between 1991 and the other years are believed due to few tag recoveries in 1991.

All of these fisheries have been addressed more extensively in other reports. This presentation focuses on conditions and catches in recent years, although a brief historical review is also given.

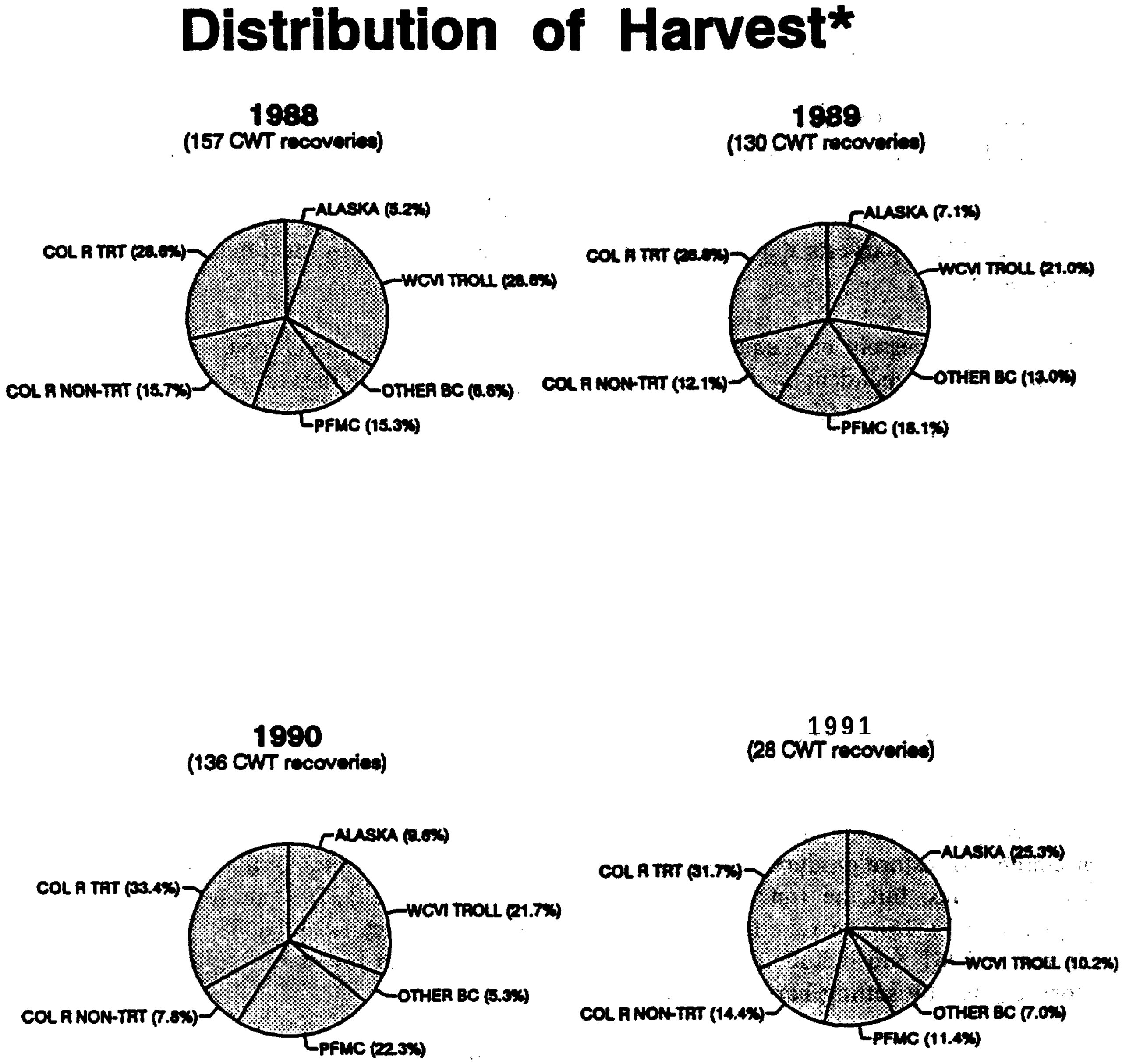
4.2.1 Southeast Alaska Troll, Net and Sport

This review of Alaska salmon fisheries is limited to waters in Southeast Alaska, where the principal concern over the effects of Alaska fisheries on Columbia River stocks. exists. Salmon fisheries occur throughout the marine waters of Southeast Alaska, i.e., the Southeast-Yakutat Region of the state (Region I). Fishing is conducted with troll, net, and sport gear.

Alaska troll fisheries are limited to Region I. These fisheries occur in state territorial waters within three miles of the surf zone, and outside three miles in waters under federal jurisdiction. The troll fishery is the major chinook-directed fishery in Southeast Alaska, traditionally accounting for about 90 percent of the region's chinook harvest (PSC 1991).

The net fisheries in Region I are purse seine, drift gillnet, set gillnet, floating fish traps, and hatchery cost recovery. Restrictions are placed on where each gear can be used. The purse seine fishery is the most mobile, and least area restricted, of the Region I net fisheries

Most of the sportfishing harvest in Southeast Alaska is in marine waters, and occurs primarily from mid-April through September, but there are opportunities for fishing the entire year. Chinook salmon is the preferred species for sportfishing in Southeast Alaska (Suchanek 1991).



* Calculated in Adult Equivalents.

Source: CTC 1992; CRITFC 1993.

Figure 17. **Distribution of harvest of Lyons Ferry Hatchery releases of subyearling fall chinook, catch years 1988-91. The patterns are assumed to represent wild Snake fall chinook, except in 1991 when few tags were recovered. Abbreviations: WCVI - West Coast Vancouver Island; PFMC - all US. marine fisheries south of Canadian border; COL R Non-T - Columbia River non-treaty; COL R TRT - Columbia River. treaty.**

4.2.1.1 **History**

The troll fishery had its beginnings in the early 1900's in the southern districts of Southeast Alaska The fishery developed with improving gear, vessels, and industry support, and expanded northward over the next several decades (ADFG 1975). Harvests of chinook salmon reached sustained average annual levels of more than 500,000 through the first half of this century. However, these harvests declined rapidly in the 1950's caused by declines in chinook salmon abundance.

Troll fishing vessels and equipment improved as the fishery developed, and this made the fishermen less dependent on daily shore-based support. Effort and harvest in the outer coastal and offshore areas increased through the 1970's.

The early commercial net fisheries in Southeast Alaska used several gears including beach seines, purse seines, gillnets, and traps. Purse seining quickly became the dominant fishing method, in terms of harvest, once the traps were removed, and power blocks were introduced during the 1960's. The use of set gillnets was eliminated from the Southeast Area, and restricted to Yakutat in 1972.

The sport fishery for chinook operated with only minor restrictions through 1975. Restrictive regulations, including area closures and reduced bag limits, have also been imposed in recent years to provide for rebuilding of some local chinook stocks (Suchanek 1991). Sport fisheries are now limited to a portion of the overall catch ceiling set for the S.E. Alaska fisheries.

Following the decline in chinook production in the 1950's, the Alaska Board of Fisheries attempted to restore production through time, area, and harvest limits on the inside net, troll, and sport fisheries, but the runs were still depressed in the late 1970's. In response, the Board implemented a 15-year rebuilding program for the Southeast chinook stocks. This program was started in 1981 and included reduction and control of harvest levels by implementing selected closures, and by setting harvest ceilings.

The mixed-stock nature of the Southeast Alaska fisheries, in particular the troll fishery, also caused concern regarding effects of the fisheries on other depressed chinook salmon stocks originating outside Alaska This concern led to establishment of guideline harvest levels starting in 1981. These guideline levels were set by the Board of Fisheries and the North Pacific Fisheries Management Council. The process for setting these levels and the managing authorities were changed by the Pacific Salmon Treaty starting with the 1986 season.

Some of the chinook salmon populations of concern are produced in transboundary rivers (systems that originate in Canada and flow through Alaska). The Board of Fisheries has held to a philosophy of 'shared ownership and coordinated management of the transboundary stocks by implementing regulations consistent with the terms of the Pacific Salmon Treaty.

4.2.1.2 Management Process and Jurisdictions

The State of Alaska has management jurisdiction over fish resources within its boundaries, including those within 3 miles of its coastline. The responsibility and authority to manage and protect these resources are placed, by statute, with the Alaska Department of Fish and Game (ADFG). ADFG regulates harvest within guidelines and criteria established by two other governmental entities that have important roles affecting Alaskan fisheries. First, the Alaska Board of Fisheries is made up of fishing industry and public members appointed by the governor. The Board sets rules and guidelines for operation of particular fisheries by adopting, as regulations, specific management plans and criteria that establish fishing methods, locations, seasons, harvest levels, harvest allocations, and management procedures. The adopted regulations must be consistent with sustained-yield management, and must result in equitable allocations of the target resources among competing user groups.

The second entity is the Commercial Fisheries Entry Commission. The Commission is provided information on the numbers of fish available for harvest in each fishery by the Board of Fisheries. The Commission uses this information with other economic and historic data to determine the number of fishermen (permits) that will be allowed to enter each fishery.

ADFG has in-season management flexibility to assure that the intent of regulations adopted by the Board of Fisheries is achieved. If ADFG determines that continued operation of a fishery under adopted regulations will result in harvest rates, levels, distributions, or allocations at variance with the Board's intent, they can modify the regulation by an emergency order procedure.

Annual chinook harvest ceilings are established by the PSC and adopted as regulations by the Alaska Board of Fisheries. The ceilings include a base harvest level plus an additional allowance for state hatchery production increases after the terms of the Pacific Salmon Treaty. The Board also allocates the total harvest ceiling among the competing fisheries in Southeast Alaska

The Board has allocated a target ceiling of 20,000 chinook (excluding hatchery add-on) for net fisheries, although there are currently no chinook-directed net fisheries. The allowance is given for incidental catches in non-chinookdirected fisheries.

The Board of Fisheries establishes seasons, locations, and methods for recreational fisheries by adopting specific fishery and area management plans as regulations. The Board incorporates guidelines and criteria established by the PSC under terms of the Pacific Salmon Treaty into its regulations. The Board allocates a portion of the chinook salmon harvest ceiling established through the PSC to the Southeast Alaska recreational fisheries (an additional provision is made for harvesting fish associated with local hatchery returns). The commercial troll fishery has been managed to harvest chinook salmon in excess of those taken by the other fisheries, up to the base ceiling (Suchanek 1991).

4.2.1.3 Participants

Over 2,500 commercial salmon permits were issued per year between **1987-90** for Southeast Alaska. Over 60 percent of these are troll permits.

Angler effort (angler-days) in the coastal waters of Southeast Alaska has averaged over 87,000 per year in recent years. The large majority of this effort is directed at salmon. Effort consists of an increasing number of non-Alaskan residents. In **1989, 5** 1% of the anglers were non-resident.

4.2.1.4 **Harvest**

The large majority of chinook caught in Southeast Alaska are taken in troll fisheries (Table 7). The sport and net fisheries combined take about 20% of the total chinook catch. Total catch has averaged less than 350,000 fish in recent years. Harvest by the sport fishery has increased since 1977, but especially since 1987.

4.2.1.5 Catch Concentration of Listed Stocks

The proportion of the catch consisting of Snake River wild fall chinook has been estimated using the PSC chinook model (Gary Morishima ***personal communications***). Lyons Ferry Hatchery releases of tagged subyearlings are assumed to be representative of wild fall chinook (CTC 1992). The catch of Snake fall chinook is consistently less than one **fish** per 1,000 total chinook caught **(<** 0. **1%),** averaging about one-third per 1,000 catch in both the troll and net/sport fisheries (Table 7; Figs. 18-19).

No estimates have been made of how many Snake River wild spring-summer chinook are caught in these fisheries. The proportion of these stocks in the catch is thought to be much less **than for** Snake fall chinook, however. The exploitation by ocean fisheries of these' stocks is considered to be approximately 10% or less of that estimated for Snake fall chinook.

4.2.2 **British Columbia Troll, Net and Sport**

Extensive salmon fisheries are conducted throughout the coastal waters of British Columbia and form the backbone of the Canadian fishing industry on the Pacific Coast **(Pearse** 1982). Large catches of chinook are taken by trolling along the West Coast Vancouver Island and the **North** and Central Coasts of the mainland. Canadian troll fisheries are the largest open ocean fisheries for salmon on the Pacific Coast of North America **(PSC** 1991). Major sport fisheries occur **along** Vancouver Island, in the Strait of Georgia, and off northern British Columbia

Table 7. Catches of chinook salmon in troll, net, and sport fisheries in Southeast Alaska, 1987-92, and estimated wild Snake River fall chinook (SRFC) caught per 1,000 total chinook landed.[1/]

	Troll		Net		Sport	
Year	Catch	SRFC/1000	Catch	SRFC/1000	catch	SRFC/1000
1987	242,025	0.5	15,254	0.0	24,300	0.5
1988	231,281	0.2	21,537	0.0	26,200	0.7
1989	235.73 1	0.4	27,611	0.0	31,100	0.0
1990	287,93 1	0.2	30,043	0.0	51,200	0.7
1991	263,756	0.0	37,627	0.0	60,400	0.3
1992	183,475	NA	3 1,627	NA	NA	NA
Average	240,700	0.3	27,283	0.0	38,640	0.4
77-86 Ave.	272,200		26,500		21,000	

1/ Source: Based on catch composition estimates produced by the PSC chinook model.

4.2.2.1 History

The industrialization of salmon fisheries along the coast of British.Columbia followed the same pattern as in regions to the north and south, Periods of expansion occurred with new technologies and markets, as well as being fueled by an almost unrestricted access to harvesting over much of this century.

The commercial catch of chinook steadily increased between the turn of the century and the mid-1980's. This increase was due mainly to increasing interceptions of chinook originating in the U.S., and especially from the Columbia River (Pearse 1982). As of 1982, "American fish" were estimated to account for 40 to 50 percent of the catch in the north and central coast areas, 20 to 45 percent in the Strait of Georgia and 70 to 90 percent off the west coast of Vancouver Island (Pearse 1982).

The commercial salmon fleet in British Columbia today is highly sophisticated, and could be considered one of the world's most advanced small boat-fleets (Pearse 1982). Since the inception of limited entry licensing in British Columbia, fleet size has declined from the high of 6,100 vessels in 1969 to about 4,300 today (DFO 1992). However, as the number of boats has declined, the power of the remaining fleet has increased due to technological advances. The recreational fishery for salmon expanded substantially in the 1980s, particularly in the Strait of Georgia

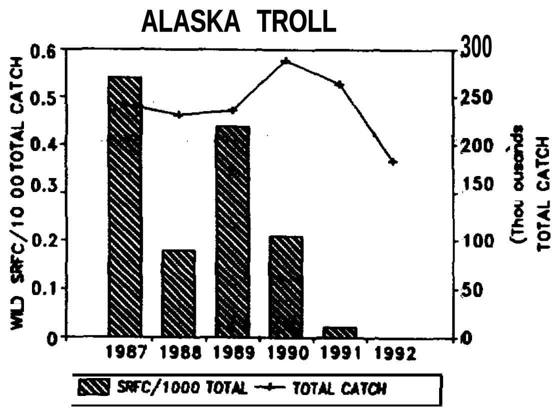


Figure *1%.* **Estimated Snake** River wild fall chinook caught in Southeast **Alaska troll fisheries** per 1,000 chinook landed, 1987-1991, **and** total chinook **landed, 1987-1992.**

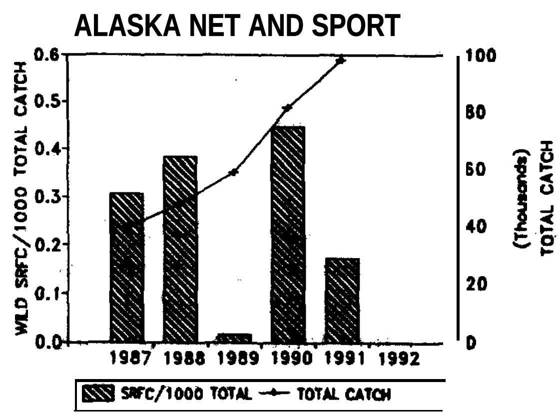


Figure 19. Estimated **Snake** River **wild fall chinook caught in Southeast Alaska** net **and sport fisheries combined** per **1,000 chinook landed, 1987-1991, and total chinook** landed, **1987-1992.**

The most significant event in the past decade was the ratification of the Pacific Salmon **Treaty,** which now forms the basis for managing much of the chinook harvest in British Columbia. Catch levels off the West Coast Vancouver Island **(WCVI),** along the North and Central Coasts, and in Georgia Strait were reduced as a result of the Treaty.

4.2.2.2 **Management Process and Jurisdictions**

As described previously, catch ceilings for most of the major chinook fisheries are recommended by the Pacific Salmon Commission **(PSC)** to the federal governments of each country. Once these ceilings are adopted by the Canadian government, implementation of **fisheries** associated with these ceilings is handled by the Canadian Department of Fisheries and Oceans (CDFO), a federal agency. That agency is required to manage the fisheries covered by the Treaty according to the conditions agreed to through the PSC.

Chinook fisheries managed through the PSC include:

- Troll fisheries off the WCVI, North and Central Coasts, and Strait of Georgia;
- Net fisheries off the North and Central Coasts; and
- Sport fisheries off the North and Central Coasts and Strait of Georgia

The growing WCVI sport fishery does not operate under management regimes established by the PSC, and until **very** recently, estimates of catches in this **fishery** (with the exception of the Barkley Sound area) had not been provided by CDFO to U.S. delegates in the PSC process (not available for this report).

The DFO manages all other fisheries not considered by the PSC. As noted, however, catch statistics are not collected in some areas.

Tribal involvement in the management process is not as well defined as in Washington and Oregon. An umbrella Indian fisheries organization is now participating with governmental authorities in “co-managing” some elements of the process, which is in a state of transition.

4.2.2.3 **Participants**

In 1991, 4,345 vessels actively participated in the salmon fishery off British Columbia: 527 seiners, 1,639 gillnetters, 857 **gillnet/trollers** and 1,335 trollers (CDFO **1992).** Vessels **targeting** chinook would primarily have been trollers. The troll fleet has declined from 3,200 to the current 2,200 over the past 20 years **(PSC** 1991). Canadian Indians owned about **20%** of the **total** privately-owned salmon fleet in 1991 (CDFO 1992).

No recent estimate of the number of recreational angler effort was **obtained** for this report. An estimated 1.8 million angler days were expended in the Strait of Georgia in 1980, which probably comprised 90 percent of the coastwide **sportfishing effort** in British Columbia **(Pearse** 1982). The large majority of that effort was directed at chinook and **coho**. Sport effort has likely increased significantly since then, particularly off the WCVI.

4.2.2.4 **Harvest**

Approximately 60% of the chinook caught in mixed-stock fisheries off British Columbia are taken in troll fisheries (Table 8; note that this table only includes catches for mixed-stock areas). Of these, the majority are caught off the West Coast Vancouver Island. Total catch of chinook in marine mixed-stock fisheries, not including certain sport fisheries for which no catch estimates were available at the time of writing, has averaged approximately 860,000 in recent years.

Table 8. Catches of chinook salmon in marine mixed-stock **fisheries** off **British Columbia, 1987-92, and estimated wild Snake River fall chinook (SRFC) caught per 1,000 CM catch." Catches are shown for troll fisheries along the West Coast Vancouver bland (WCVI) and the North and Central Coasts (N/C) and in all other marine mixed-stock fisheries combined.**

Year	WCVI troll		N/C troll		Other	
	Catch	SRFC/1000	Catch	SRFC/1000	Catch	SRFC/1000
1987	378,931	1.7	239,693	0.8	268,792	0.10
1988	408,724	1.3	181,907	0.5	342,558	0.11
1989	203,695	2.7	244,947	0.9	319,813	0.01
1990	297,974	0.5	179,130	0.4	387,933	0.12
1991	202,910	1.5	220,625	0.2	395,564	0.17
1992	335,300	NA	179,600	NA	NA	NA
Average	304,589	1.5	207,650	0.6	342,932	0.10
77-86 Ave.	457,300		234,800		666,400	

1/ **Based on catch composition estimates produced by the PSC chinook model.**
Source: CTC (1992).

4.2.2.5 Catch **Concentration** of **Listed** Stocks

The proportion of the chinook catch consisting of Snake River wild fall chinook was estimated using the PSC model, as described in section 4.2.1.5. Results indicate that the highest relative abundance of Snake fall chinook occurs off the WCVI, where the average catch of this stock per 1,000 total landed averages about 1.5 fish (Pig. 20). The catch of this stock in troll fisheries further north averages about 0.6 fish per 1,000 total catch (Pig. 21). Relative impacts to Snake fish is less per 1,000 chinook caught in all other British Columbia fisheries combined (Pig. 22).

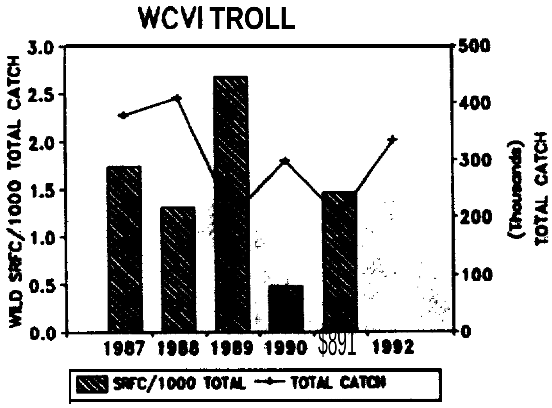


Figure 20. **Estimated Snake River wild fall chinook caught in the WCVI troll fisheries per 1,000 chinook landed, 1987-1991, and total chinook landed, 1987-1992.**

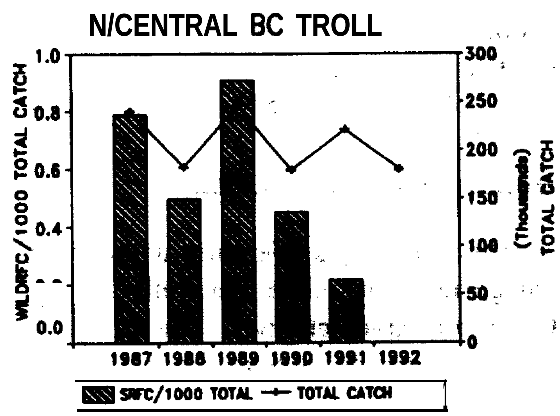


Figure 21. **Estimated Snake River wild fall chinook caught in the North/Central B.C. troll fisheries per 1,000 chinook landed, 19874991, and total chinook landed, 1987-1992.**

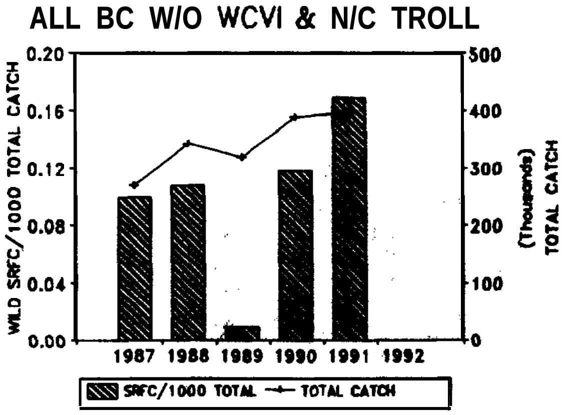


Figure 22. Estimated Snake River wild fall chinook caught in all B.C. marine fisheries excluding the WCVI and N/C troll fisheries per 1,000 chinook landed, 1987-1991, and total chinook landed, 1987-1991. Data are incomplete for 1992.

No estimates have been made of how many Snake River wild spring-summer chinook are caught in these fisheries. The proportion of these stocks in the catch is thought to be much less than for Snake fall chinook, however. The exploitation by ocean fisheries of these stocks is considered to be approximately 10% or less of that estimated for Snake fall chinook.

4.2.3 Washington Marine Troll, Net and Sport

Commercial and recreational salmon fisheries operating within Washington marine areas can be grouped into geographic categories that relate generally to management jurisdictions and approaches as they affect Columbia River chinook. The categories are fisheries in the Puget Sound/Strait of Juan de Fuca area, fisheries in coastal bays and estuaries, and ocean fisheries.

Treaty Indian and non-treaty fisheries within Puget Sound/Strait of Juan de Fuca are primarily targeted on large runs of hatchery salmon returning to Puget Sound and wild runs (sockeye and pink) returning to the north sound and Fraser River. Extensive commercial and sport fisheries occur throughout these waters, though restrictions have increased in recent years to protect weak runs of wild salmon. Two tribes conduct troll fisheries within the Strait of Juan de Fuca.

Salmon fisheries off the Pacific Coast include treaty Indian and non-treaty commercial troll fisheries, and the non-treaty sport fishery. Four tribes along the northwest coast of Washington manage independent troll fisheries. Each tribal fishery operates in a defined area along the coast, although some of the areas overlap.

Non-treaty commercial salmon fishing in the ocean off Washington is limited to trolling. The Washington troll fleet targets chinook and coho salmon; large numbers of pink salmon are harvested in odd-numbered years. The recreational fisheries primarily target chinook and coho also; other species are pursued during closures for salmon seasons.

Small numbers of non-local chinook are caught in fisheries within estuaries along the Washington Coast (major ones being Grays Harbor and Willapa Bay). Some Columbia River chinook are taken in these fisheries.

4.2.3.1 History

Tribal fisheries have occurred in some form in the area for centuries. Interference from the arrival and expansion of the non-Indian population, loss of resources to commercial development@ competing fisheries, and denial of access and opportunity by governmental actions reduced the tribal fisheries to remnants of what they had been. By the 1960s, tribal fisheries harvested only about 10% of the total Puget Sound salmon catch. The federal court ruling of 1974 (U.S. vs. *Washington*) changed the status dramatically and opened the way for reestablishing tribal fisheries as important components in the over all management picture. The tribal fisheries developed rapidly during the 1970s and 1980s. Ocean troll fisheries have been established and are managed by the Makah, Quileute, Hoh, and Quinault tribes. Klallam bands also have troll fisheries, but these are limited to inside the Strait of Juan de Fuca.

The non-treaty commercial fishery began in the late 1800s. The fishery started as-a low-mobility effort limited mostly to rivers and estuaries, and then developed during the early 1900s into a very mobile fleet of purse seine and gillnet vessels.

Any person who applied for a commercial fishing license in Washington and paid-the fee could get one prior to 1975. Because of this, and the relatively small investment required to enter the gillnet fishery, the number of Puget Sound licenses increased from 325 in 1935 to over 900 by the mid-1960s. The number of purse seine licenses remained constant at about 375-400 throughout this period. The Salmon License Moratorium Law of 1974 established a maximum number of salmon licenses at the numbers issued at that time.

Prior to World War II, the marine sport fishery was fairly limited to locations around the major population centers, such as Seattle, Tacoma, and Everett. The fishery expended rapidly after the war and soon included all of Puget Sound and the Strait.

Prior to the 1970s the ocean troll fishery was virtually unlimited, except for minor season and size-limit restrictions. The unregulated expansion of the fleet, together with gradually diminishing resources, led to conflicts and allocation disputes between the troll fishery and competing sport and net fisheries. The troll fleet grew in numbers dramatically between 1950 and 1970. There were about 1,300 vessels in the fishery in 1951, but by 1967 the number had increased to 2,372. Most of this increase was from recreational boats being licensed to make commercial landings. The use of hand-held recreational gear was eliminated from the fishery by state legislation in

1973. In addition, the Salmon License Moratorium Law of 1974 placed a ceiling on the number of Washington commercial troll licenses that is still in effect

The **ocean** sport fishery experienced a similar pattern of growth **and** decline as seen in the troll fisheries. For example, by 1976, there were 569 licenses issued for Washington charter vessels. A moratorium-and buy-back program was established by the **Washington** Legislature, and, by 1990 the number of licenses issued had been reduced to 269.

The ocean fisheries off Washington declined during the 1980s for two principal reasons. The first was the implementation of weak stock management, exercised initially to protect weak runs of wild **coho** salmon, then to protect Columbia River chinook. The second reason was due to the decline of major chinook stocks in the Columbia River (e.g., Spring Creek Hatchery)' that supported much of the **ocean** harvest off Washington.

4.2.3.2 Management Process and Jurisdictions

The tribal troll and net fisheries are managed by the respective tribes under their own management plans and approaches. This management is coordinated with the State of Washington using ***rules*** and mechanisms established by the Federal ***Court in U.S. vs. Washington,*** or as developed **through** negotiations of **the parties**. Tribal management must also be compatible with, **and** is somewhat constrained by, actions and jurisdictions of the PSC and PFMC.

Non-treaty fisheries within, Washington marine waters are managed by the Washington Department of Fisheries **(WDF),** consistent with terms of the Pacific Salmon Treaty, sharing principals established by the Federal Court in U.S. ***vs.*** *Washington* end/or by **agreements with** tribal managers, and actions of the PFMC. The processes involved in developing annual management plans were described in Sections **4.1.1, 4.1.2,** and 4.1.3. **Management of all fisheries** within these waters has grown immensely complex in recent years in response to the number of jurisdictions involved and the decline of many wild stocks.

4 3 3 3 Participation

An average of about 800 vessels have participated in the non-treaty troll fishery off Washington since 1987 **(PFMC** 1993a). This represents less than 20% of the total **average number of troll** vessels that operated over that period in U.S. waters south of the **Canadian** border. **The** number of vessels participating in the fishery is less than **one-third** of what it was in the late **1970s.**

Over this same period, the annual average number of angler-days expended in the ocean sport salmon fishery in **Washington** waters was about **130,000.** This amount is **about 25% of the average** number of angle&days expended between **1976-80** in **these** same waters **(PFMC 1993a).**

No data on fishery participation for treaty ocean fisheries nor **Puget** Sound **fisheries were** summarized for this report.

433.4 **Harvest**

Nearly 80% of the chinook harvest in marine waters between Cape Falcon (near Astoria) **and** the Canadian border occurs inside Puget Sound and the Strait of Juan de Fuca (Table 9). Ocean catches of chinook have declined sharply since the **1970s** due to restrictions imposed to protect Columbia River stocks and a general decline in chinook abundance. The total number of chinook caught in the ocean north of Cape Falcon has averaged less than 100,000 fish in recent years (Table 9).

Table 9. **Catches** of chinook salmon **in Washington and Oregon marine waters north of Cape Falcon,** 1987-92, **and estimated** number **of wild** Snake River **fall chinook (SRFC) caught** per 1,000 **total catch.**[1/]

Year	Ocean Troll		Ocean sport		Puget Sound[2/]	
	Catch	SRFC/1000	Catch	SRFC/1000	Catch	SRFC/1000
1987	80,900	1.0	44,500	1.3	316,000	0.3
1988	107,70	2.6	19,400	3.3	339,700	0.5
1989	74,7000	2.5	20,800	2.4	389,600	0.4
1990	64,400	0.2	32,900	0.0	375,700	0.2
1991	50,300	3.0	13,300	4.1	233,500	0.4
1992	68,400	NA	18,900	NA	NA	NA
Ave.	74,400	1.8	24,967	2.2	330,900	0.3
77-86 Ave.	133,200		89,200		425,673	

1/ Based on catch **composition estimates produced** by the PSC chinook **model.**

2/ **Includes** Strait of **Juan** da Fuca.

Source: **PFMC** (1993) for catch **statistics.**

4.2.3.5 catch **Concentration** of **Listed Stocks**

The number of wild Snake fall chinook caught inside Puget Sound/Strait of Juan de Fuca is estimated to average about 0.3 fish for every 1,000 chinook landed (Table 9; Fig. **23),** based on PSC chinook modeling results. **The** CWT recovery data used in the modeling procedures indicate that the relative abundance of Snake River fish is higher in the Strait than in deep Puget Sound, **however.**

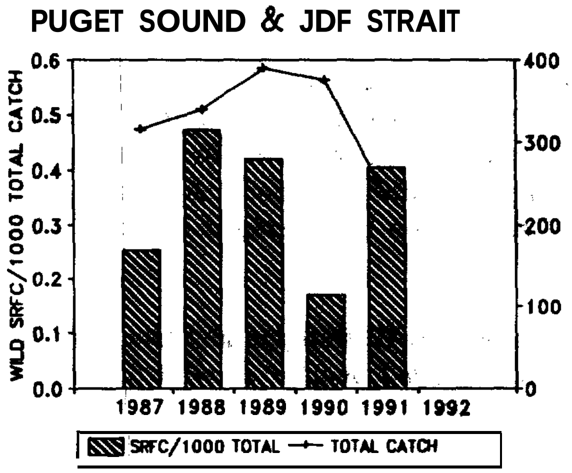


Figure 23. Estimated Snake **River wild** fall **chinook caught** in **Puget Sound and Strait** of **Juan de Fuca fisheries per** 1,000 **chinook landed, 1987-91, and** total **chinook landed,** 1987-1991. Data **are** incomplete for 1992.

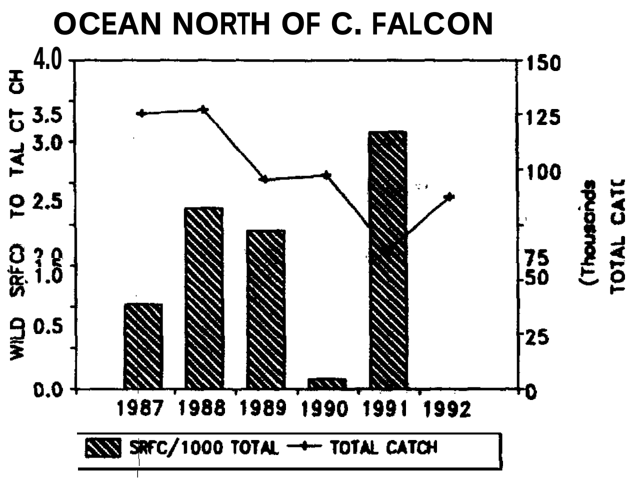


Figure 24. Estimated Snake **River** wild **fall** chinook **caught** in **ocean troll and sport fisheries** north of Cape **Falcon** per 1,000 chinook **landed,** 1987-1991, **and** total chinook **landed, 1987-1992.**

In contrast, the number of wild **Snake** fall chinook caught in ocean fisheries north of Cape Falcon is estimated to average about two **fish** for every 1,000 chinook landed **(Table** 9; Fig 24). This relative abundance exceeds all other marine fishery areas (Pig. 11). **Only** in **the mainstem** Columbia do catches of Snake River fish per 1,000 chinook landed appear to be higher.

No estimates have been made of how many Snake River wild spring-summer chinook are caught in these fisheries. The proportion of these **stocks** in the catch is **thought to** be mu& **less than** for Snake River fall chinook, however.. **The** exploitation of these stocks is considered to be approximately 10% or less of that estimated for Snake **fall** chinook.

43.4 Oregon and California Marine Troll, Net and Sport

Sport and commercial troll fisheries for chinook **salmon** occur **all** along the coasts of Oregon and California to south of San Francisco. Chinook are the predominate salmon species off California

4.2.4.1 History

The history of ocean salmon fishing off California and Oregon is similar to that of areas to the north with regard to fleet expansion, technological advancements, and **the recent** decline of the fishery in response to weak **stocks. In general, however,** catches of chinook have remained remarkably stable through the years, attaining record, or near record, levels in 1987 and 1988.

In recent years the chinook fisheries south of Cape Falcon have been constrained to protect the threatened Sacramento River winter chinook run, and to reduce impacts on **Klamath** River fall chinook **(PFMC** 1993). Sacramento River winter chinook have **been** listed as threatened under the ESA.

4.2.4.2 Management Process and Jurisdictions

The states of Oregon and California manage commercial troll and recreational fisheries within their respective boundaries. However, as **discussed above** for Washington **marine** fisheries, state regulation of salmon fisheries must be in harmony with PFMC regulations and management objectives. The PFMC sets harvest ceilings, seasons, area/time **closures, and** other restrictions on the fisheries.

The Oregon and California fisheries are contained **in PFMC** management **planning** for **the area** south of Cape Falcon.

4.4.4.3 Participation

An average of about 3,700 vessels have participated in the troll, **fisheries off Oregon and California** since 1987 **(PFMC** 1993). This is less than **one-half the** number of **vessels that** operated **in** these fisheries in **the** late 1970s.

Over this same period, an annual average number of **angler-days** expended in the ocean sport salmon fisheries off Oregon and California was about 430,000, roughly **90%** of the **1976-80** average **(PFMC** 1993).

4.2.4.4 Harvest

Harvests of chinook salmon in both the California and Oregon troll fisheries have increased since 1971. The **five-year** mean catch for California increased from **563,000** for **1971-1975** to **795,000** for 1986-1990. The Oregon five-year mean harvest increased **from** 203,000 to 397,000 for **the** same periods. Chinook harvests in the recreational fisheries have not varied much during this time. The California recreational fishery **averaged 170,000 chinook** per year in **1971-1975,** and 166,000 per year in 1986-1990. The Oregon fishery averaged 41,000 and 36,000 during the same periods. Catches for 1987-92 are shown in Table **10.**

Table 10. Commercial and sport catches of chinook salmon in marine waters off California and Oregon south of Cape Falcon, 1987-92.

YOU	Troll Catch	Sport Catch
1987	1,400,400	247,100
1988	1,785,100	209,100
1989	883,800	217,200
1990	653,600	163,000
1991	368,900	94,300
1992	267,000	84.100
Ave	1,018,400	186,140
76-86 Ave.	710,600	129,300

Source: PFMC (1993).

4.2.4.4 Catch Concentration of Listed Stocks

Snake River fall chinook are assumed to be distributed throughout the area between Cape Falcon and Northern California, based on recoveries of Lyons Ferry Hatchery releases. Estimates of **catch** concentration for Snake **fall** chinook have not been made by year **for this** area as was done for north of' Cape Falcon using the PSC chinook model. **Application** of that model **is** limited to fisheries north of Cape **Falcon.** The chinook model used in the **PFMC planning process** does not incorporate stock composition data in the manner applied in the' **PSC** model.

We therefore estimated an overall average number of wild Snake River fall chinook caught per 1,000 chinook landed by a simple comparison of CWT recoveries of Lyons Ferry Hatchery fish north (to the U.S./Canada border) and south of Cape Falcon. Data for brood years 1984-86 were used. The estimated numbers of tagged fish caught in U.S. fisheries in 1987 to 1991 were nearly equal in each catch area: 59 and 62 tagged fish for north and south of Cape Falcon, respectively. We assumed therefore that the numbers of wild Snake fall chinook caught in these two areas was approximately equal in these catch years and scaled the estimate of Snake fish per 1,000 chinook caught to the number estimated north of Cape Falcon.

This procedure gives an average estimate of 0.2 Snake River fall chinook per 1,000 chinook landed for catch years 1987-91 south of Cape Falcon (Fig. 13). The concentration of this stock relative to other chinook stocks in the catch is higher, however, off Oregon than off California, as seen in the distribution of CWT recoveries. We made no attempt to estimate catch concentration for areas smaller than the entire range of chinook south of Cape Falcon.

4.25 Columbia River

Extensive commercial and recreational fisheries occur below the confluence of the Snake River that potentially impact Snake River stocks. Limited ceremonial and subsistence fisheries can also occur within the Snake subbasin by tribal fishers.

The principal fishing locations of tribal fishers occur in Zone 6, which extends for 130 miles upstream of the Bonneville Dam (Fig 25). Fishing is by set gillnet, dipnet and hook and line. Commercial and ceremonial and subsistence fisheries occur in that area.

Non-Indian commercial fishing takes place in the 140 miles of river below Bonneville Dam (Zones l-5). Fishing is conducted using drift gillnets. Neither Oregon nor Washington allow commercial fishing within the tributaries that produce major runs of salmon and steelhead in this area; these include the Willamette, Cowlitz and Lewis rivers.

The sport fishery below the Snake confluence occurs principally below Bonneville Dam. The fishery in this reach consists of the "lower Columbia fishery", between Bonneville Dam and the Astoria-Megler Bridge;' and the Buoy 10 fishery, which occurs in the estuary below the Astoria-Megler Bridge. Extensive sport fisheries for salmon also occur in some tributaries below Bonneville, such as in the Willamette, Cowlitz and Lewis rivers.

4.2.5.1 History

Salmon fisheries have occurred in the Columbia River for countless generations by tribal fishers. The abundant salmon runs gave rise to much more intensive fisheries after the arrival of non-Indians, followed by the decline of the wild runs, as has been wel) documented elsewhere.

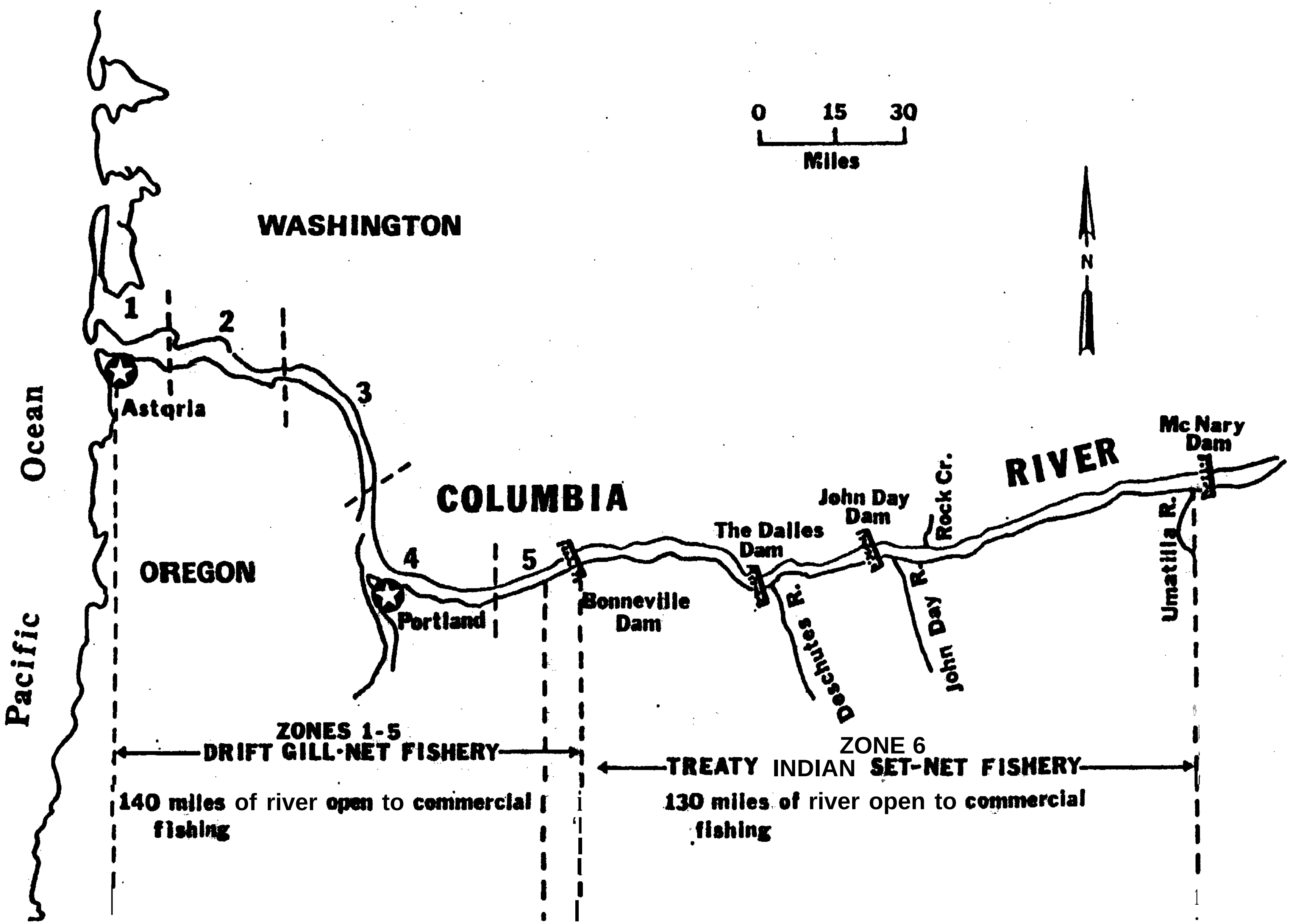


Figure 25. Map of the Columbia River below McNary Dam showing areas open to commercial fishing.

The commercial fisheries that developed above Bonneville Dam (Zone 6) remained open to both Indians and non-Indians until 1956, when Celio **Falls** was inundated by the completion of **the Dalles** Dam. This event ended centuries of tribal fishing at **this location.** In 1957, joint **action of** Oregon and Washington closed Zone 6 to commercial fishing. Treaty **Indian** fishing that occurred there between **1957-68** was by tribal ordinance.

As a result of ***Puyallup*** vs. ***Washington,*** the states reestablished commercial fishing above Bonneville Dam in 1968, for exclusive use by tribal fishers **(WDF/ODFW** 1992). In 1969, the Zone 6 fishery was shaped in regard to area, river mouth closures, dam **sanctuaries,** and gear regulations. The upper commercial fishing deadline was raised to the **mouth of** the **Umatilla** River. The fishery is now conducted mainly with set **gillnets,** though **dipnetting occurs from** scaffolds erected near the Bonneville and **Dalles** dams **(WDF/ODFW** 1992).

As a result of U.S. ***vs. Oregon,*** provision was made in 1974 to **enable the tribes** to secure up **to** 50% of the harvestable number of fish, as well as to participate in **the cooperative management** of the runs. Tribal **fisheries** include both commercial **fishing** and **harvest for ceremonial and** subsistence purposes.

Commercial fishing by non-Indians in the river is a history of booms **and** busts. **Due** to **the** decline of upriver wild runs, the numbers of days open to **commercial** fishing **below Bonneville** Dam has declined dramatically over the past **50** years. No summer **season** his **occurred since** 1964 and no spring season since 1977. No **sockeye season** occur& **in 1973-83 or in 1989 to** present. No August season occurred in **1980-86 (WDF/ODFW** 1992). **Hatchery runs have largely** supported the fisheries in the past two decades.

The **recreational** fisheries have generally **experienced increased** angling **opportunities from 1984** to present due to increased abundance of **some** runs, **notably lower river spring runs and certain** upriver fall chinook runs. The Buoy 10 fishery has become **extremely popular.**

4.2.5.2 Management Process and Jurisdictions

Columbia River fisheries are managed according to **the** Columbia River **Fish Management Plan (CRFMP;** see *Section* **4.1),** adopted **by** the **U.S. District** Court **in 1988. The plan provides a** framework for defining allocations between **treaty** and **non-treaty fisheries and spawning** escapements for the major upriver runs of salmon and steelhead. The process for establishing fisheries **was** described in **Sections** 4.1.3 and **4.1.4.** The: reader **should** refer **to the actual plan** for details on how harvest levels and **allocations** are defined for various **sizes** of **each major run.**

The plan provides no specific provisions for addressing spawning **escapements** of **individual fish** populations like those produced in the Snake River system. Harvest **levels are to be established** on the basis of the sizes of population aggregates passing **specified dams.**

4.253 **Harvest**

The harvest of all fall chinook in the Columbia River has averaged about ***280,000* fish** since 1987 (Table 11). This compares to catches of between 400,000 to 800,000 fish during the **1940's**. About 65% of the average since 1987 has consisted of fish comprising the up-river run and **mid-**Columbia bright run; all of these are produced above Bonneville and **include** hatchery and wild **fish**. Snake River fall chinook are considered a part of the up-river bright run, comprising less than one percent of this chinook run (Columbia River Technical **Staffs** 1992).

The catch of lower river fall chinook stocks, fish produced below Bonneville, has averaged slightly less than 100,000 fish annually since 1987 **(Table** 11). The large **majority** of **these fish** are of hatchery origin. These stocks are caught predominantly in non-treaty fisheries.

The harvest of spring chinook in the **mainstem** Columbia River has averaged about 25,000 fish annually since 1987 (Table $2). Approximately **60%** of these fish are produced by runs originating below Bonneville Dam, principally in **the Willamette**. On average 25,000 additional spring chinook are harvested by sport fisheries in tributaries below **Bonneville**, the large majority in the Willamette.

An average of nearly 10,000 spring chinook have been harvested from runs **produced** upstream of Bonneville since 1987, with over 60% of these being taken by the treaty Indian **fishery** in Zone 6 (Table 12). The large majority of the treaty catch is taken for ceremonial and subsistence purposes. Still, these ceremonial and subsistence catches have not been **adequate to provide** the minimum amount allowed by the **CRFMP,** including catches of summer chinook.

Non-treaty catches of summer chinook since 1987 are estimated to be zero (Table 13). An average of less than 800 summer chinook is estimated to have been caught in treaty fisheries during this time, all being taken incidentally in **fisheries** directed at **sockeye.** No **summer chinook** directed fisheries **have** occurred on the river since 1965.

4.2.5.4 **Catch Concentration of Listed Stocks**

An estimated average of three Snake River wild fall chinook have been **caught** for each **1,000** total fall chinook caught in the Columbia River since 1987 (Table 11; **Fig.26), based** on **estimates** of stock composition from Joint Technical Staffs (1992).

It should be noted, as was discussed in Section 2 that if the **Join Staffs'** estimates of **dam** conversion for fall chinook are excessively high, then their estimates of Snake **fall** chinook run size and catch would also be high (their estimates of dam conversion rates are used in run **reconstruction).** If dam conversion is closer to 5 **%** loss per dam **(based on** *Chapman et al.* **1991),** then the estimated average number of Snake fall chinook per 1,000 chinook landed **would** be closer to 1.5 since 1987 (values estimated for all fisheries in this report would **decrease** by about *50%).*

Table 11. Catches of adult fall chinook in the mainstem Columbia River and estimated wild Snake River fall chinook (SRFC) caught per 1,000 total catch?

	Up- and Mid-River Runs				Lower River Runs					
	Treaty	Non-treaty			Treaty	Non-treaty			Grand	SFRC/
Year	Indian	Comm.	Sport	Total	Indian	Comm.	Sport	Total	Total	1000
1987	144,600	130,300	20,700	151,000	800	196,200	36,200	232,400	528,800	2.4
1988	150,700	121,000	19,700	140,700	1,900	197,700	25,400	223,100	516,400	3.8
1989	134,800	93,600	18,300	111,900	0	37,700	20,200	57,900	304,600	2.3
1990	84,600	39,400	8,400	47,800	200	5,300	8,800	14,100	146,700	1.4
1991	55,900	27,100	10,300	37,400	400	13,400	10,400	23,800	117,500	4.2
1992	29,000	12,000	7,300	19,300	200	4,900	10,900	15,800	64,300	3.9
Ave.	99,933	70,567	14,117	84,683	583	75,867	18,650	94,517	279,717	3.0
77-86 Ave	60,700	38,100	4,600	42,700	500	50,900	6,400	57,300	160,700	

1/ Based on Joint Technical Staffs (1992) and PFMC (1993).

Table 12. Catches of adult spring chinook in the mainstem Columbia River, 1987-92.”

Year	Runs Above Bonneville				Runs Below Bonneville			Grand Total
	Treaty Indian	Non-Treaty			Non-Treaty			
		Comm.	Sport	Total	Comm.	Sport	Total	
1987	6,700	1,000	400	1,400	10,600	2,400	13,000	21,100
1988	7,000	5,100	1,400	6,500	13,200	3,200	16,400	29,900
1989	6,300	1,500	500	2,000	12,400	2,500	14,900	23,200
1990	7,000	2,100	3,100	5,200	16,200	9,100	25,300	37,500
1991	4,100	900	1,500	2,400	11,700	4,100	15,800	22,300
1992	5,800	200	1,200	1,400	4,900	4,100	9,000	16,200
Ave.	6,150	1,800	1,350	3,150	11,500	4,233	15,733	25,033
77-86 ave.	5,600	1,300	1,700	3,000	7,400	2,600	10,000	18,600

1/ Based on Joint Technical Staffs (1992) and PFMC (1993).
source: Does not include sport catches in Cowlitz and Lewis

Table 13. Catches of adult summer chinook in the Columbia River, 1987-92.

Year	Treaty Indian	Non-Treaty
1987	1,200	0
1988	1,100	0
1989	100	0
1990	<100	0
1991	100	0
1992	100	0
Ave.	800	0
77-86 Ave.	4,500	<150

Source: PFMC (1993).

Table 14. **Estimated** wild **Snake** River **spring chinook (SRSC) caught** per 1,000 **total** catch of **spring** chinook in **the mainstem** Columbia River, **1987-91.**[1/]

Year	Non-treaty SRSC/1,000[a]	Treaty SRSC/1,000	Total SRSC/1,000
1987	12.8	132.2	50.8
1988	50.0	175.4	79.4
1989	12.8	107.6	38.6
1990	15.6	90.0	29.5
1991	16.5	118.0	35.2
Ave	21.5	124.6	46.7

1/ From Joint Technical Staffs (1992).

Estimates of the number of Snake River spring chinook caught per 1,000 total spring chinook landed in the **mainstem** Columbia since 1987 **differ** significantly **between** treaty and non-treaty fisheries (Table 14). Non-treaty fisheries operate on a larger quantity of fish, consisting of large numbers of fish that are produced in tributaries below Bonneville. For all **mainstem** fisheries combined, an estimated average of 47 wild Snake River spring chinook have been caught for every 1,000 total spring chinook landed since 1987 (Table 14.)

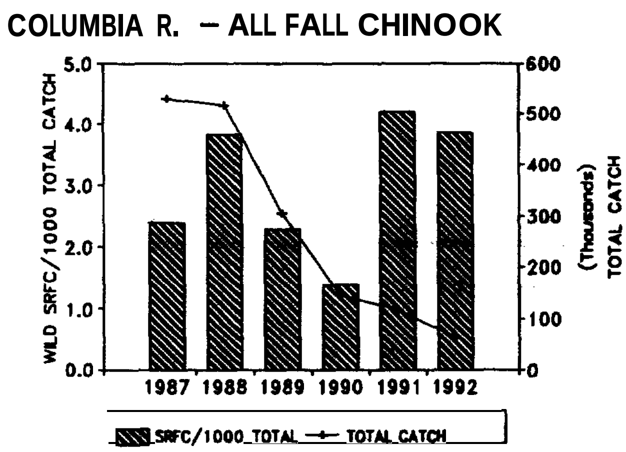


Figure *26.* **Estimated** Snake Riverwild fall chinook **caught** in the Columbia River per 1,000 chinook **landed,** 1987-1991, **and total** chinook **landed, 1987-1992.**

5.0 HARVEST MANAGEMENT STRATEGIES

Harvest impacts to Snake River salmon are tho consequence of these fish being intermingled with healthier fish populations that are targeted by fisheries. Of the stocks of interest in this report, fishing mortality is highest on Snake River fall chinook, which are currently subjected to a total exploitation rate in excess of 60% on a brood year basis. This population of fish is caught in all of the major marine mixed stock fisheries between Northern California and Alaska. In addition, the adults of this population migrate up the Columbia River at the same time as do some of the major salmon runs that support significant fisheries in the mainstem. These healthier runs consist of both wild and hatchery stocks.

Impacts by ocean fisheries is much less on Snake River spring-summer chinook and sockeye than on fall chinook. The ocean exploitation rate on spring chinook appears to be less than 5%. The rate may be slightly higher on summer chinook. No estimate has been made for sockeye, but it is likely no more than the rate for spring chinook. Total exploitation rates on these populations, therefore, including harvests in the Columbia River, appears to be less than 16% in recent years, with that rate occurring on spring chinook. Total exploitation rates are likely less on the other populations.

Based simply on the proportion of these populations that are killed by harvesting, the largest potential benefits to recovery that could be gained through harvest measures exist with Snake fall chinook (see Figs. 4 and 10). Harvest measures alone, however, even with the complete elimination of all fishing mortality, would likely be inadequate to achieve a recovered. and sustainable population of fall chinook (see Figs. 8-9). *There* is uncertainty in what level of mortality the population can sustain, given the uncertainty in productivity estimates.-

Much smaller potential benefits appear to exist for spring-summer chinook and sockeye than for fall chinook, based solely on the amount of fishing mortality estimated to currently occur on these populations. Total elimination of fishing mortality on these stocks in the absence of other remedial actions would likely be of limited benefit to the populations.

Alternative harvest management strategies exist that theoretically could be implemented to reduce these harvest impacts on Snake River salmon. In reality, however, some of these strategies would be extremely difficult to implement, if not impossible, given available information on stock distribution and timing In addition, some of these strategies would require much improved run size forecasting capabilities for chinook, both for the Snake River population and other stocks comprising the major mixed stock areas as well. Forecasting techniques are currently considered to be quite poor for chinook with a few exceptions, such as for Robertson Creek on Vancouver Island (Gary Morishima *personal communications*).

We have made no attempt to analyze the merits or potential problems with strategies described in the following sections, other than in a very cursory manner. Serious attempts to implement any of these strategies would require a comprehensive analysis.

Most of the strategies described here are variations of the two most commonly referred to salmon management approaches, escapement goal and harvest rate management. (PSC 1991). Both approaches result in increasing harvest as stock abundance increases, and decreasing harvest as stock abundance decreases. Under escapement goal management, the objective is to annually regulate harvest depending on abundance so as to achieve a particular spawning escapement level. Under harvest rate management, the objective is. to achieve a particular exploitation rate (a maximum rate in the case of recovery) on the stock, with both catch and escapement fluctuating depending on abundance (PSC 1991). Both approaches are intended to control harvest to levels that a stock can sustain.

The strategies described below are treated separately, although it would be likely that certain combinations of strategies, or their components, would be used In attempting to implement harvest management measures for recovery purposes.

5.1 SINGLE WEAK STOCK MANAGEMENT

This management strategy recognizes that inherent differences exist in productivities between stocks intermingled in mixed-stock areas, and attempts to limit harvest on the basis of the single weakest stock each year. Different stocks might be limiting in different years.

Most of the major fisheries along the coast, including those in the Columbia River, have operated under a “strong stock” concept over most of this century. To some extent, many of these fisheries still operate in such a manner although consideration is now being given to the needs of weaker stocks.

This strategy was originally developed as a way of limiting fishery impacts in mixed-stock areas to both the allocation and reproductive requirements associated with the stock identified to be weakest. The concept of weak stock management is currently being used to varying degree&in developing management plans off Washington; Oregon and California (PFMC 1992a). Similar considerations are also being given for some Columbia River fisheries (Joint Technical Staffs 1992).

Management for the “weakest stock” is nearly impossible to implement in reality, however, without vastly improved knowledge about stock composition in each fishery area, a clearer definition of stocks and their productivities, and explicit management objectives and decision criteria for each major fishery. Notwithstanding its limitations, a formalized stock management approach could be implemented in one or more of the fisheries that currently harvest Snake River salmon. To implement such a strategy would require a clear set of decision rules and management criteria for each fishery of concern. Most forms of so called weak stock management today operate without such rules and criteria, making the design of annual management plans subject to poorly defined objectives and negotiation between parties.

Strict weak stock management for Snake River salmon form&ted on the basis of the limits of sustainable exploitation rates (see Figure 9) could potentially lead to massive reductions or elimination of fisheries across the range where these stocks are located. Given the potential of

Snake River fall chinook to be located in nearly every marine fishery along the coast, this could change the face of salmon fisheries radically. Fisheries would be forced to terminal areas. Within the Columbia, fisheries would to a large extent be moved to the tributaries where surplus production of individual stocks could be harvested.

Single weak stock management would be implemented on the basis of a minimum escapement goal for each Snake River stock or by setting a maximum total exploitation rate for all fisheries combined. In either case, great difficulty would exist in equitably allocating the allowable impact between all of the fisheries that harvest the stock. The allowable exploitation rate would need to be defined within a context of how much mortality would be allowed from other human-induced sources.

Implementation could be given to allowing a sliding scale of impacts in response to annual variations in abundance of the stock of concern, although&e problems stated earlier about current forecasting techniques would likely make this unfeasible.

5.2 MULTIPLE WEAK STOCK MANAGEMENT

This approach would incorporate the status of more than one stock in determining the allowable impacts within various fisheries. If for example, five different potentially weak stocks are of concern to the fisheries of a region, then the status of all five would be considered in setting harvest levels. Status levels would be defined for each stock of concern. For example, if the status of each stock is defined as being within one of three levels, with Level 1 being the most depressed, then the allowable harvest for all fisheries would be set by a pre-determined rule that defines harvest impacts by how many stocks are at Level 1, Level 2 and Level 3. All fisheries managed under such an approach would be conducted each year according to consistent, pre-determined stepped harvest amounts over a range of abundances far the stocks of concern. Capabilities for making good pre-season run size projections would make this strategy difficult to implement. A simpler variation would be to aggregate stocks of a given production type for various areas, and make decisions about fishery levels on -the basis of the status of those aggregates.

If the number of stocks that are potentially threatened grows, this concept may offer a structured way of developing fishery rules that incorporate the status of many stocks. Such an approach would provide more stability to mixed stock fisheries than would occur under single weak stock management. The approach would not be adequate to fully protect a single stock that is perennially weak compared to the-others. A decision rule could be designed to cover that possibility, making the approach at that point identical to single weak stock management.

This concept has been developed for possible implementation with coho fisheries north of Cape Falcon (Western Washington Tribes 1988) and who fisheries off the West Coast Vancouver Island (U.S. Southern Panel 1992).

5.3 TIME-AREA SEPARATION

This strategy attempts to design fisheries in a manner to minimize mixed-stock conflicts by harvesting at times and places before stocks come together or after they separate along their migration paths. The concept would likely be impractical in the ocean given the highly mixed nature of the populations and the likelihood that Snake fall chinook are so widely distributed, especially with the limited amount of data currently available on ocean distribution patterns. It should be noted also that the in-river run timing of Snake River fall chinook is likely typical of wild fish, which almost always is much more protracted than for hatchery fish, making time separation more difficult to manage for.

This concept is sometimes combined with enhancement efforts in order to create hatchery runs that return to locations in a manner that allows full harvest without impacting wild runs. The Youngs Bay enhancement project is an example of area separation of stocks. Early returning runs of hatchery steelhead in many streams are an example of time separation; allowing for high harvest rates on hatchery fish without impacting later running wild fish. In these cases, the use of wild broodstocks, or at least the maintenance of wild type characteristics such as run timing, is not preferred.

Time-area separation is the basis for some of the harvest management actions now in place for Columbia River fisheries. For example, the non-treaty commercial spring chinook fishery is limited to the "winter season" to avoid excessive impacts on the wild Upriver stocks that migrate later.

Some opportunities likely exist for further developing the use of time-area separation in managing certain Columbia River fisheries. Current policies of Oregon and Washington prohibit non-treaty commercial fishing in the tributaries that support major runs of fish. Those areas are managed solely for the recreational fisheries. Consideration could be given to re-examining these policies in light of ESA concerns. Twenty years of management under U.S. vs. *Washington* in Puget Sound and along the Washington Coast have demonstrated that commercial and sport fisheries can co-exist in rivers often smaller than Columbia tributaries. Hatchery re-programming could occur so that hatchery production is more clearly linked to specific harvesting strategies that minimize conflicts with the ESA.

5.4 SELECTIVE HARVEST FISHERIES

Most fisheries today cannot discriminate between the various stocks of fish that are present in a particular area. Those that do use some form of live capture technique, such as hook and line, beach seine, purse seine or trap, combined with visual identification of the origin of the fish, as by a mark. Fisheries have a greater capability, however, to select on the basis of size. This occurs in most or all sport and troll salmon fisheries on the Pacific Coast (undersized fish must be released).

Selective fisheries on the basis of visual identification of marks is currently being considered by the Washington Department of Fisheries for coho in Puget Sound. That agency has proposed marking all hatchery coho salmon that are released into Puget Sound for the purpose of reducing harvest impacts on wild stocks. Fish would be marked with a ventral fin clip. Returning hatchery adults could then be positively identified in sport, and perhaps purse seine, fisheries. Wild fish would need to be released. Similar ideas might be considered for hatchery chinook in the Columbia Basin, although chinook appear to suffer higher mortalities following capture and release. Also, the multiple age structure of chinook populations would subject fish to repeated capture if the method was used in ocean fisheries. Such an approach would likely have more potential in hook and line fisheries within the mainstem Columbia.

These techniques could not be used for managing the mainstem gillnet fisheries. Incentives could be provided, however, to encourage the development of trapping methods that would allow for live capture by commercial fisheries.

The concept of using size selection in fisheries may be of benefit to Snake River chinook. Fisheries might be developed in the Columbia, for example, that harvest a much greater proportion of smaller and younger fish, thereby reducing impacts on older age classes. This would increase the potential productivity of the spawning escapement (see Section 2.5).

5.5 CEILING FISHERIES

Certain chinook fisheries in British Columbia and Alaska are currently managed through ceilings set by the PSC. Although the approach as currently designed is regarded by many as inadequate to meet the needs of fisheries and stocks, it could be redesigned to make it more effective (PSC 1991). One approach being considered is to allow the ceilings to change in response to years of exceptional survival or because of low abundance of stocks of concern. This latter situation would incorporate something like the procedure described under Multiple Weak Stock Management.

5.6 INCREASED HATCHERY PRODUCTION AND CATCH CEILINGS

This strategy would consist of dramatically increasing hatchery production from Columbia River hatcheries, as well as from other hatcheries that contribute heavily to major mixed-stock fishing areas, in order to decrease the concentrations of Snake River chinook within those areas. The concept, sometimes referred to as “flooding”, would also incorporate catch ceilings in the major fisheries. Theoretically, catch levels could then be maintained while decreasing exploitation rates on Snake River fish.

This concept would incorporate new terminal area fisheries, or expanded fisheries, to harvest the increased returns of hatchery fish. These fisheries would be located to avoid impacting returning runs of Snake River fish.

The feasibility of successfully implementing this kind of a strategy on the scale that would be required is questionable. Such an approach would also likely result in large surpluses of hatchery fish in areas because of harvest constraints to protect weaker stocks.

REFERENCES

Alaska Department of Fish and Game (ADFG). 1975. Southeast Region king salmon stock status report prepared far the Program Review Committee. Alaska Department of Fish and Game, Div. Comm. Fish., Juneau, Alaska. 10 p.

Allendorf, F., N. Ryman, and F. Utter. 1987. Genetics and fishery management: past, present, and future. *In N.* Ryman and F. Utter, eds. Population Genetics and Fishery Management. University of Washington Press, Seattle and London.

Aro, K.V., and M.P. Shepard. 1967. Pacific salmon in Canada Pages 225-327 *in* Salmon of the North Pacific Ocean. Part IV. Spawning populations of North Pacific salmon. International North Pacific Fisheries Commission Bulletin 23.

Atkinson, C.E., J.H. Rosa, and T.O. Duncan. 1967. Pacific salmon in the United States. Pages 43-223 *in* Salmon of the North Pacific Ocean. Part IV. Spawning populations of North Pacific salmon. International North Pacific Fisheries Commission Bulletin 23.

Berkson, J. 1991. Coded wire tag analysis on Snake River spring, summer, and fall chinook. Columbia River Inter-Tribal Fish Commission, Portland, Oregon - February 19, 1991. Letter to NMFS, ETSD, Portland, Oregon. 7 p. + tables and figures.

Burgner, R.L. 1991. Life history of sockeye salmon (*Oncorhynchus nerka*). *In* C. Groot and L. Margolis, eds. Pacific Salmon Life Histories. UBC Press, Vancouver, British Columbia.

Canadian Department of Fisheries and Oceans. 1992 fact sheet. Published by Pacific Region.

Chapman, D., A. Giorgi, M. Hill, A. Maule, S. McCutcheon, D. Park, W. Platts, K. Pratt, J. Seeb, L. Seeb, and F. Utter. 1991. Status of Snake River Chinook Salmon. Prepared for the Pacific Northwest Utilities Conference Committee. Don Chapman Consultants, Inc. Boise, Idaho. 394 p. + Appendices.

Chinook Technical Committee (CTC). 1988 1987 annual report Pacific Salmon Commission, Report TCCHINOOK (88)-2. Vancouver, British Columbia

Chinook Technical Committee (CTC). 1992. 1991 annual report. Pacific Salmon Commission, Report TCCHINOOK (92)-4. Vancouver, British Columbia

Columbia Basin Fish and Wildlife Authority (CBFWA). 1991, Integrated system plan for salmon and steelhead production in the Columbia River Basin; Report submitted to the Northwest Power Planning Council, Portland, Oregon.

Columbia River Technical **Staffs.** 1992b. Biological assessment of the impacts of anticipated 1992 summer and fall season Columbia River fisheries on listed Snake River species under the Endangered Species Act. Prepared in conjunction with the Technical Advisory Committee and the U.S. Fish and Wildlife Service.

Columbia River Technical Staffs. 1992a Biological assessment of the impacts of proposed 1992 winter and spring season in-river fisheries on listed species **proposed for** listing under the Endangered Species Act. Prepared in conjunction with the Technical Advisory Committee and the U.S. Fish and Wildlife Service.

Columbia River Inter-Tribal Fish Commission (CRITFC). 1993. Snake River fall chinook fact sheet (3rd ed.). Unpublished table, Columbia River Inter-Tribal Fish Commission, Portland, Oregon. 1 p.

Fisher, J.P., W.G. Pearcy, **and** A.W. Chung. 1983. Studies of juvenile **salmonids** off the Oregon and Washington coast, 1982. Oregon State University College of Oceanography Cruise Report 83-2; 41 p.

Fisher, J.P., W.G. Pearcy, and A.W. Chung. 1984 and 1983. Studies of juvenile salmonids off the Oregon and Washington coast, 1982. Oregon State University College of Oceanography Cruise Report 83-2; Oregon State University Sea Grant College Program **ORESU-T-85-004:** ***29*** p.

French, R., H. Bilton, M. Osako, and A. Hartt. 1976. Distribution and origin of sockeye salmon ***(Oncorhynchus nerka)*** in offshore waters of the North Pacific Ocean. International North Pacific Fisheries Commission Bulletin 34: 113 p.

Hartt, A.L., and **M.E.** Dell. 1986. Early oceanic migrations and growth of juvenile Pacific salmon and steelhead trout. International Pacific Fisheries Commission **Bulletin 19:141** p.

Healey, M.C. 1980a The ecology of juvenile salmon in Georgia Strait, British Columbia Pages 203-229 ***in*** W.J. McNeil and D.L. **Himsworth,** eds. Sdmonid Ecosystems of the North Pacific Oregon. Oregon State University Press, **Corvallis,** Oregon.

Healey, M.C. 1980b. Utilization of the Nanaimo River estuary by juvenile chinook salmon, ***Oncorhynchus tshawytscha.*** Fisheries Bulletin **77:653-668.**

Healey, M.C. 1991. Life history of chinook salmon, p. 331-393. ***In: C.* Groot** and L. **Margolis** (eds.). Pacific Salmon Life Histories. UBC Press, Vancouver, **British Columbia.**

Healey, M.C. 1983. **Coastwide** distribution and ocean migration patterns of stream- and ocean-type chinook salmon, ***Oncorhynchus tshawytscha.*** Canadian Field-Nature **97:427-433.**

Hilbom, **R.,** and C.J. Walters. 1992. **Quantitative Fisheries** Stock Assessment: **Choice,** Dynamics and Uncertainty. Chapman and Hall, New York and London. **570 p.**

Larkin, P.A. 1977, An epitaph for the concept of maximum sustainable yield. Transactions of the **American Fisheries** Society **106:1-11.**

Ludwig, D., and C.J. Walters. 1981. Measurement errors and uncertainty in parameter estimates for stock and recruitment. Canadian Journal of Fisheries and Aquatic Sciences **38:711-720.**

Matthews; G., and R. **Waples.** 1991. Status review for Snake River **spring** and summer chinook salmon. NOAA Technical Memorandum NMFS **F/NWC-200.**

McIsaac, D. 1990. **Factors** affecting the abundance of 1977-79 brood wild fall chinook salmon **(*Oncorhynchus tshawytscha*)** in Lewis River, Washington. Doctoral dissertation. University of Washington, Seattle. 174 p.

Mecum, RD. 1991. 1990 Southeast Alaska-Yakutat salmon net **fisheries.** Part 2 ***'In*** 1990 **Finfish** Report to the Board of Fisheries. Alaska Departmentof Fish and Game, Div. **Comm.** Fish., Juneau, Alaska Pages 2.1-2.60.

Mendel, G.D. Milks, R. Bugert, **K.** Petersen. 1992. **Upstream** passage and **spawning** of fall chinook salmon in the *Snake* River, **1991. Washington Department** of **Fisheries Completion** Report to U.S. Fish and Wildlife Service, Cooperative Agreement No. **14-16-0001-91502.**

Miller, D.R, J.G. Williams, and C.W. **Sims.** 1983. Distribution, **abundance,** and **growth** of juvenile salmonids off the **coast** of **Oregon** and Washington, summer **1980. Fisheries** Research **2:1-17.**

Morishima, G.S. 1984. **Wildfish:** realities of management ***In* S.M.** Walton and D.B. **Houston,** eds. Proceedings of the Olympic Wild Fish **Conference, March 23-25, 1983, Port** Angeles, Washington.

Morishima, G.S. 1992. Briefing packet for ESA **Recovery Team --** harvest **management** implications for potential recovery of Snake River fall chinook. Unpublished material.

Morishima, G.S. 1993. Distribution of Columbia River, **Washington Coastal,** and **Puget Sound** chinook salmon stocks. Final report **submitted** to Public Utility **District** 81 **of Clark** County, Vancouver, Washington. 14 p + appendices.

National Marine Fisheries Service **(NMFS).** 1992. Biological **opinion for** the **1992** fisheries conducted under the Fishery Management Plan for the salmon fisheries off **Washington,** Oregon, and California. Northwest Region of the National Marine Fisheries Service, Portland, Oregon.

Nelson, K. and M. Soule. 1987. Genetical conservation of exploited fishes. In N. Ryman and F. Utter, eds. Population Genetics and Fishery Management. University of Washington Press, Seattle and London.

Pacific Fishery Management Council (PFMC). 1993. Review of 1992 ocean salmon fisheries. Portland, Oregon.

Pacific Fishery Management Council (PFMC). 1992b. Preseason report III. Portland, Oregon.

Pacific Fishery Management Council (PFMC). 1992a Review of 1991 ocean salmon fisheries. Portland, Oregon.

Pacific Salmon Commission (PSC). 1991. A report to the Pacific Salmon Commission on a workshop held at Vancouver, B.C., January 10 and 11, 1991, to explore alternative chinook management approaches. Pacific Salmon Commission, file 72006.

Pearse, P.H. 1982. Turning the tide: a new policy for Canada's Pacific Fisheries. The Commission on Pacific Fisheries Policy, Final Report, Vancouver, British Columbia 292 p.

Petrosky, C., and H. Schaller. 1992. A comparison of productivities for Snake River and lower Columbia River spring and summer chinook stocks. Prepared for Proceedings of Salmon Management in the 21st Century: Recovering Stocks in Decline. 1992 Northwest Pacific Chinook and Coho Workshop, Boise.

Reisenbichler, R.R. 1990. Sustainable harvest rates for spring chinook salmon in the upper Columbia Basin. *In:* Status and Future of Spring Chinook Salmon in the Columbia River Basin--Conservation and Enhancement. NOAA Technical Memorandum NMFS F/NWC-187.

Ricker, W.E. 1.975. Computation and Interpretation of Biological Statistics of Fish Populations. Fisheries Research Board of Canada, Bulletin No. 191.

Ricker, W.E. 1981. Changes in the average size and average age of Pacific salmon. Canadian Journal of Fisheries and Aquatic Sciences 38:1636-1653.

Schaller, H., and T. Cooney. 1992. Snake River fall chinook life-cycle simulation model for recovery and rebuilding plan evaluation. Unpublished report, Oregon Department of Fish and Wildlife and Washington Department of Fisheries. 18 p. + Appendices.

Suchanek, P.M. 1991. Overview of major recreational fisheries of Southeast Alaska Report to Alaska Board of Fisheries. Alaska Department of Fish and Game, Div. Sport Fish, Douglas, Alaska.

U.S. Southern Panel. 1992. Stepped harvest management approach for **coho.** Unpublished report of the U.S. Section, Southern Panel of the Pacific Salmon Commission, for the Southern Panel Coho Workshop, February 11, 1992.

Waples, R, R Jones, Jr,, B. Beckman, and G. Swan. 1991. Status review for Snake River fall chinook salmon. NOAA Technical Memorandum NMFS **F/NWC-201.**

Waples, R., R. Jones, Jr., B. Beckman, and G. Swan. 1991. Status review for Snake River fall chinook salmon. NOAA Technical Memorandum NMFS **F/NWC-201.**

Washington Department of Fisheries and Oregon Department of Fish and Wildlife **(WDF/ODFW)**. 1992. Status report for Columbia River fish runs and fisheries, 1938-91. Joint report. 225 p.

Western Washington Tribes. 1988. Salmon and steelhead management and allocation plan. Draft proposal. Available from the Northwest Indian Fisheries Commission, Olympia, Washington.